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PALAEOOLIMNOLOGY

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ABSTRACTS

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VTH INTERNATIONAL SYMPOSIUM ON PALAEOCLIMATOLOGY

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RECENT LAKE ACIDIFICATION: REVERSIBILITY STUDIES USING LAKE
SEDIMENTS

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The cause-effect relationship between acid deposition and lake acidification is well established. Diatom analysis of sediment cores has been used extensively to provide evidence of such acidification (e.g. Battarbee et al 1985). In several lakes in Galloway, south-west Scotland, diatom analysis of cores from 1986 has provided evidence of a reversal of the acidification trend. Battarbee et al (1988) attribute this to the decline in UK sulphur emissions of roughly 40% since 1970.

This study (currently in the first year of a three year postgraduate programme) has two principle aims:
i) to establish any floristic reversal in the diatom record of Galloway lakes with confidence.
ii) to develop techniques suitable for monitoring possible future trends.

A single lake basin where evidence of the floristic reversal has been observed, the Round Loch of Glenhead, will be the basis of the study. A multiple coring strategy, preferably using freezer-coring techniques to maximise resolution of the lake sediment record, will be carried out during the summer of 1989. Sediment trapping techniques and methods of sampling the living diatom community will be adapted to allow monitoring of the possible reversibility trend.

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Nature 332: 530-532

VARIABILITY OF DIATOM STRATIGRAPHY IN VARVED LAKE SEDIMENTS

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Varved, or annually laminated lake sediments, provide an accurate chronology without the need for radiometric dating methods. They also permit rapid and accurate quantitative determinations of microfossil concentrations and accumulation rates, while the minimal mixing of the sediments and good time control can be used to assess the variability of various aspects of palaeolimnology.

Variability in palaeolimnological data is a source of error still largely ignored in most studies. For example, to assess between core differences in diatom accumulation rates requires cross correlation or dating of individual cores; both methods have inherent errors, making the reliable matching of synchronous horizons difficult. Varved sediments permit the comparison of the diatom content of synchronous time intervals with considerable precision.

Diatom percentages and accumulation rates are presented for a number of varved sediment sequences from a lake in northern Sweden (Kassjön). A transect of surface cores were taken using a freeze-corer and cover a range of water depths: deep-water cores with clearly repeatable varves are contrasted to shallow-water bioturbated profiles. Even between deep-water varved sequences, percentages and accumulation rates are variable, suggesting that diatom deposition is complex and has severe implications for palaeoecological interpretations.

LITHOSTRATIGRAPHY OF THE 250,000-YEAR LACUSTRINE SEDIMENTS CORE FROM
VALLE DI CASTIGLIONE CRATER (ROMA): PALAEOHYDROLOGICAL INFERENCES.

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The sediments drilled by the borehole (88 m deep), performed in the middle of the drained lake bed (1 Km diameter), were studied through macroscopic observations and several grain size, mineralogical and geochemical analyses. The catchment area, made up of pyroclastic rocks, was subject of detailed geomorphological investigations.

The overall distribution of the lithotypes in the lithostratigraphic sequence has been strongly controlled by the climatic variations, as the clastic sediments have been deposited during wet climatic phases, while the sediments with prevailing chemical component (mainly calcium carbonate), have been formed during relatively dry climatic phases.

By contrast, the characteristics of the sediments, i.e. structural, grain size and, partly, geochemical, have been conditioned by the different hydrological situations that involved the area following one another.

On this ground, the lithostratigraphic sequence can be roughly subdivided into three portions: the lower part, characterized by constant grain size, by presence of laminated structures and low amount of detrital content, can be related to the phase in which Valle di Castiglione was isolated by the lacustrine basin of Pantano Borghese, situated S of the crater, and/or in connection with this latter, with outflow located E of the crater; the central part, characterized by variable grain size, by disappearance of the laminated structures, and high amount of detrital content with reworked mollusc remains, can be related to the phase in which Valle di Castiglione was in connection with Pantano Borghese, with outflow located N of the crater; the uppermost part of the sequence, characterized by decreasing detrital content and by local occurrence of peat, can be related with the phase in which Valle di Castiglione was in connection with Pantano Borghese, with outflow located W of the crater.

²⁴¹AM DATING OF LAKE SEDIMENTS

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Although ²¹⁰Pb is now routinely used for dating recent lake sediments problems frequently arise over the interpretation of data from sites with disturbed sediment records. Since the early 1970's ¹³⁷Cs measurements have provided valuable evidence for evaluating very recent accumulation rates. Until the Chernobyl accident the only source of this isotope was fallout from atmospheric testing of nuclear weapons, and comparisons of the ¹³⁷Cs record in the sediments with the atmospheric fallout allowed in some cases confident identification of the depths representing 1954, the date in which ¹³⁷Cs fallout was first recorded, and 1963, the year of peak deposition.

¹³⁷Cs dating is not universally applicable, one of the major problems being the mobility of ¹³⁷Cs within the sediment column. Many recent studies have shown that peak ¹³⁷Cs activities occur too close to the surface to represent 1963, and continue to be measurable at depths well below those representing 1950. With the passage of time these problems will increase. The problem has recently been exacerbated by the fallout of ¹³⁷Cs from the Chernobyl accident. In regions of high fallout downwards diffusion of Chernobyl ¹³⁷Cs has obliterated the weapons-testing ¹³⁷Cs profile.

Fallout from nuclear weapons testing also contained traces of a second long-lived radioisotope, ²⁴¹Am (half-life 432 yr). This isotope is readily measured through its gamma emissions at 59.5keV using low background counting systems. A growing data set from lakes with a wide range of pH values suggests that ²⁴¹Am is considerably less mobile than ¹³⁷Cs, and provides a relative secure means of identifying sediments from the early 1960's. With the passage of time this marker will become of increasing value.

FUNCTION OF SEDIMENTARY STRUCTURES AS PALEOLIMNOLOGICAL INDICATORS

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Abstract

The character and activity level of physical, chemical, and biological processes regulates the deposition and redistribution of sediment and thereby also the composition and structural organization of the sedimentary sequence. Improved methods of sediment sampling and the recording and dating of sedimentary structures have increased the possibilities for using such structures as paleolimnological indicators. However, understanding of the past requires insight into the processes that form the structures. Stereoradiographs of rectangular, unextruded sediment cores have proved to be valuable three-dimensional documents for analysing the formation of primary and secondary sedimentary structures. They also facilitate core correlation and often make possible rapid and very detailed inter-core correlations. They are therefore used for monitoring environmental changes in some lakes and coastal bays in Sweden. The formation of contemporary sedimentary structures is studied by comparing stereoradiographs of cores collected from selected locations during different seasons, and also before and after a specific event such as a massive algal bloom, a major storm or a severe flood. Gaps in the sedimentation sequence are determined by using radiographically computed sedimentation-compression curves. Stereoradiographs of sedimentary structures in growing sedimentary sequences reflect well-documented cyclic and less frequent, episodic changes in the depositional environment.

TAPHONOMY AND DIAGENESIS IN DIATOM ASSEMBLAGES: A LATE PLEISTOCENE EXAMPLE FROM LAKE MAGADI, KENYA.

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Palaeolimnological interpretation of fossil diatom assemblages from saline lakes is dependent on studies of modern syn- and aut- ecology, such studies have been undertaken in Africa by Gasse (1986). However, by no means all fossil assemblages possess a modern analogue. The extreme fluctuations in salinity which characterise many closed lakes lead to high spatial and temporal variability in diatom communities (Gasse, 1988). Taphonomic processes then produce assemblages containing taxa with mutually incompatible ecological distributions. Diatom frustules in saline-alkaline lakes are also susceptible to dissolution, the silica is often diagenetically transformed into zeolites.

These problems are illustrated with reference to a 9m core taken from hypersaline-alkaline Lake Magadi, Kenya whose diatom stratigraphy suggests a tripartite zonation. Zone 3 (18-17 ka.) contains a periphytic diatom assemblage dominated by *Anomeoneis sphaerophora* as found in the hot springs around Magadi today. Zone 2 (17-12.5 ka.) contains a diverse mixture of species associated with both saline (eg. *Thalassiosira faurii*, *Navicula elkab*) and freshwater conditions (eg. *Melosira granulata*, *Epithemia* spp.). Intra specific composition remains constant throughout this zone. Zone 1 is dominated by various species of the genus *Nitzschia*. *N. sp. af. fonticola* >72% dominates sub-zone 1D (c.12 ka) and appears to correspond to a deepwater phase when stromatolites formed 50m above the present lake (Hillaire-Marcel and Casanova 1987).

Zone 2 has no modern analogue and would seem to be a spatially and/or temporally mixed assemblage. Strong seasonality occurs in the region today and it is possible that the lake received periodic inputs of freshwater with subsequent postdepositional mixing of sediments. Alternatively, this fossil assemblage could incorporate diatoms from different, but contemporaneous habitats. Diatom preservation throughout this core is good although elsewhere in the basin exposed lake beds dated to the early Holocene high phase have no diatoms. Instead diagenesis of silica under the action of the highly concentrated groundwaters has produced zeolites (eg. erionite). Hot springs at the perimeter of the basin locally dilute the lake brines. The particular chemistry of these springs, in particular their alkalinity and silica contents seems to dictate whether frustules are preserved, as at the coring site or dissolved soon after deposition as occurs elsewhere in the basin.

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Hillaire-Marcel, C. and Casanova, J. (1987) Isotopic hydrology and palaeohydrology of the Magadi (Kenya)-Natron (Tanzania) basin during the late Quaternary. Palaeogeog. Palaeoclim. Palaeoecol. 58: 155-181

DISCO, A DIATOM DATABASE FOR PALAEO LIMNOLOGICAL RESEARCH

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Palaeolimnologists have a continuing need to store and manipulate large quantities of data. Consequently we have designed a database (DISCO) for both fossil and modern material, which stores diatom counts, water chemical analyses, lake catchment characteristics and core sediment descriptions; we can easily extend it to record other limnological data. Williams *et al.* (1988) have produced a complete coded version of Hartley's checklist of British diatoms which forms part of DISCO (along with a list of additional names), allowing the database user to set up sublists of taxa for checking diatom counts as they are entered or define groups of taxa to be treated as synonyms in subsequent analyses. DISCO can extract subsets of data which multivariate statistical packages or graph drawing programs can then read.

The main use of DISCO has been in the Surface Water Acidification Program (SWAP) where it has managed diatom counts from surface sediment samples with matching water chemistry from 172 lakes in Norway, Sweden and the UK (the calibration dataset for pH reconstruction) along with counts from several sediment cores (used for the reconstructions themselves). DISCO is based on widely-used database software (ORACLE) and runs on both a VAX minicomputer and an IBM AT-class personal computer.

Reference: Williams, D.M., Hartley, B., Ross R., Munro, M.A.R., Juggins, S. & Battarbee, R.W.
A Coded Checklist of British Diatoms. ENSIS publishing, London.

**Palaeolakes in south central Sahara -
Problems of palaeoclimatological interpretation**

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The results of palaeoecological studies of Holocene swamp and lake deposits of a number of endorheic depressions of the Ténéré, Kavar, Djado and Great Erg of Bilma region of eastern Niger are presented, comprising analysis of their stratigraphy, sedimentology, diatom flora and macrofossils.

The investigations demonstrate that various palaeolakes have reacted differently in space and time and by type of lake to climatic change. Some of the lakes reacted rapidly to changes of the precipitation regime, as evidenced by changing size, level, water balance and water chemistry, while perennial freshwater lakes nearby show changes relatively independent of short-term climatic fluctuations. These facts suggest a more complex influence of local and regional hydrological and hydrogeological factors on the Holocene lake evolution than a mere climatic dependence. Beyond doubt precipitation must have considerably increased during the Holocene pluvial phases, in order to produce a general rise of groundwater table(s) for the whole region. The stratigraphic and ecological status obtained for individual endorheic depressions is, however, mainly a reflection of differences among groundwater catchments and aquifers of different size, and thus of a considerable diversity of palaeoenvironmental conditions within the region at any given time of the Holocene.

This shows that one has to be cautious about drawing large scale (zonal) palaeoclimatological conclusions from palaeolimnological data, such as lake-level fluctuations, without applying corrections based on local and regional hydrology.

THE HOLOCENE PALAEO LIMNOLOGY OF A SUBALPINE LAKE, JASPER NATIONAL PARK,
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Lorraine Lake (52° 44', 117° 40') is a small subalpine lake located in the Front Ranges of the Canadian Rocky Mountains. Five sediment cores were recovered with a percussion corer which provide sensitive postglacial records. Microfossil analyses (diatoms, chrysophyte statospores, and pollen) and fossil pigment analyses (chlorophyll, oscillaxanthin, and Myxoxanthophyll) were completed on the sediments. Chronological control for the record is provided by radiocarbon dating and tephra analysis. The postglacial vegetation record indicates that ca 7000 radiocarbon years B.P. (RYBP) the vegetation changes as decreases in several arboreal and shrub taxa were observed. The record does not change again until ca 4000 RYBP when *Tsuga* pollen begins to appear regularly which may indicate cooler and moister conditions. Evidence from diatom analysis and sediment stratigraphy indicates that water levels were significantly lower than present from 9000 to 7000 RYBP. Fossil pigment stratigraphies indicate that the lake has become more productive. The oscillaxanthin concentrations peak during the early Holocene, which indicates that representation by the Oscillatoriaceae was greater than at present. The oscillaxanthin stratigraphies from different sediment cores are similar to one another, while the myxoxanthophyll stratigraphies differ from shallow versus deep sediments. The difference in these stratigraphies is likely due to more favourable conditions for growth at the shallow site.

SEDIMENTATION PATTERN IN A DEEP CLEAR-WATER LAKE IN SW SWEDEN

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The clear-water, oligotrophic Lake Skärsjön has not, unlike most other lakes in SW Sweden, become acidified. Both alkalinity and pH have remained constant during the last 15 years. The lake is also well-known because of the occurrence of the glaciomarine relicts *Pontoporeia affinis* and *Mysis occulata relicta*. In some areas around the lake the ground-water is buffered when it flows across, and partly also through, a silty glaciomarine clay containing some CaCO_3 , before reaching the lake itself. It is also clear from corings and seismograms that "windows" of this clay occur on the lake bottom, especially along steep bottom-slopes. This means that the lake water is also in direct contact with the clay. Six 6 m long cores were collected with a Mackareth corer from different parts of the lake. By using a combination of radiocarbon dates, pollen analysis, detailed lithostratigraphic descriptions, and slotting of the cores' susceptibility values sediment accumulation curves were constructed, for each core. The usually high clay content of the postglacial sediments indicates that erosion and redeposition of the glaciomarine clay have taken place throughout most of the Holocene. The sedimentation pattern in most cores indicates the presence of both irregular sedimentation and hiatuses. Together with differences in sedimentation between cores this shows that the lake might have been subject to significant water level changes.

PALEOLIMNOLOGICAL RESEARCH IN EAST-CENTRAL ELLESMERE ISLAND,
ARCTIC CANADA

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Investigations of pond and lake sediments in east-central Ellesmere Island were initiated to obtain chronological data bearing on glacier fluctuations. Because of the rugged terrain, at the northern extremity of the Canadian Shield, much of the coast is too steep to retain marine deposits. Thus, the best way to document environmental changes through time is to investigate lake basins excavated in granites and related rocks, as well as a few smaller ponds dammed by moraines.

Sediments from shallow ponds and lakes, usually with <1 m of water and which freeze to the bottom each winter, are sampled with a motor driven SIPRE-type corer. The longest core recovered was 5.85 m in length, and this core penetrated shell-bearing marine sand beneath organic pond sediments. The cores are kept frozen in the field and during shipment to Ottawa.

Larger lakes have proved to be less easy to sample. Thick ice characterizes the lakes along the outer east coast (up to 4.4 m for a lake at 480 m on Pim Island). This has necessitated the use of a hand-operated Finnish auger with flighted extensions to penetrate the ice, prior to coring with a modified Livingstone sampler driven hydraulically. The addition of an outer steel barrel equipped with tungsten carbide teeth allows the whole unit to be rotated when refusal occurs with the hydraulic unit. In this way frozen sediment was recovered at the base of a 90 cm-long core in a lake at 650 m on Knud Peninsula.

Radiocarbon dates on basal organic sediments do not exceed 9370 ± 110 years (TO-111), and lakes nearer the Prince of Wales Icefield generally contain only younger sediments. In the most extreme case, a lake at 830 m on Rundfeldt was found to be frozen to the bottom (5.45 m of ice), but dating of benthic algae in the ice below 4 m showed that the lake was open 5730 ± 70 years ago (TO-530).

The lake sediments also contain a wealth of biological and chemical indicators of past lake environments. Our primary data are presently based on abundant diatom and chrysophyte fossils, although invertebrate remains are also being investigated. Cladoceran fossils are sparse and low in species diversity, but dipteran fossils are often more diverse and plentiful. Many new taxa are being described. Because the extent of ice cover is so closely related to climate, the habitat preferences of various taxa may provide paleoclimate proxy data. In addition, these data provide important insights into lake ontogeny in these extreme environments.

Deposition of radionuclides upon an upland
drainage basin in mid-Wales

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The deposition of radiocaesium from nuclear weapons testing and the Chernobyl accident upon the Llyn Llygad Rhedol catchment in mid-Wales is described. Radionuclide inventories in lake cores dated by ^{210}Pb analysis are related to local estimates of caesium deposition and levels of activity retained in soils on the catchment.

THE CHRONOLOGY OF DEPOSITION OF RADIONUCLIDES AS RECORDED IN THE SEDIMENTS OF
PONSONBY TARN, CUMBRIA

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A study has been made of the radionuclide content of sediments from Ponsonby Tarn in Cumbria to examine the pattern of deposition of radiocaesium and actinides upon the catchment. Sediment cores obtained from the tarn in 1986 were dated by the ²¹⁰Pb method and compared with results obtained from a previous study in 1980 (Eakins and Cambray, 1985).

Sediment from the tarn contained actinides derived mainly from discharges to atmosphere. The 1986 cores contain greater quantities of weapons fallout and Sellafield derived caesium than may be accounted for by direct atmospheric input but less attributable to the Chernobyl accident than expected. An increase in sedimentation rates post 1980 together with evidence from diatom analysis suggests that catchment disturbance together with sediment focussing have contributed to the changes evident in the sediment record.

Reference: Eakins, J.D. and Cambray, R.S. (1985). Studies of environmental radioactivity in Cumbria Part 6: The chronology of discharges of caesium-137, plutonium and americium-241 from BNFL Sellafield, as recorded in lake sediments. AERE-R11182 (HMSO).

**SYNSEDIMENTARY SIDERITE FORMATION IN LAKE SEDIMENTS AS AN INDICATOR
FOR MESOTROPHIC CONDITIONS OF LACUSTRINE ENVIRONMENTS**

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Holocene lacustrine sediments out of maar lakes (Eifel Mountains, FRG) have been investigated microstratigraphically. Today these lakes show oligotrophic to eutrophic conditions. Consequently the sediment types vary from predominantly clastic (Lake Weinfelder Maar) and organoclastic (Lake Gemündener Maar) to organic (Lake Holzmaar and Lake Meerfelder Maar). Lake Laach pumice tuff appears as a distinct isochrone in the sediments of all these lakes. Meerfelder Maar and Holzmaar were absolutely dated by varve chronology. An estimated chronology was developed for Weinfelder Maar based on the occurrence of cyclic siderite laminations, which may represent true varves. This interpretation is supported by lateral extension of these laminae, pointing to a rhythmic formation at the sediment/water interface. In Weinfelder Maar siderite laminations for the first time appear approximately at the onset of the Atlantic in 290 cm sediment depth. Since Subboreal times formation of siderite shows an increasing trend to become interrupted by siderite free sections. Siderite formation ceases in the Subatlantic at 95 cm sediment depth. In Holzmaar siderite occurs between 900 and 825 cm sediment depth in Younger Dryas. Siderite formation is less distinct in Meerfelder Maar. It appears only between 810 and 780 cm sediment depth in late Allerød. Annual laminations have been proved in eutrophic lakes, where siderite layers replace autochthonous calcite in late summer.

Siderite (FeCO_3) formation is dependant on certain geochemical conditions. Hence, it provides good indications on the lacustrine environment. Siderite indicates the existence of an anoxic sediment/water interface, caused by increased microbial activity as a result of higher input of organic matter. All lakes show a trend towards a mesotrophic state due to climatic development, but at different times. This temporal modification is caused by basin morphology and catchment area. Meerfelder Maar and Holzmaar show this mesotrophic state as a short Late Glacial transition to eutrophic conditions, which remains until today. Mesotrophic conditions as a maximum in trophic state continued in Weinfelder Maar and Gemündener Maar from the onset of the Atlantic till Subboreal times.

PALEOLIMNOLOGY OF QILU HU, YUNNAN PROVINCE, CHINA

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Qilu Hu is a large ($A = 36.9 \text{ km}^2$), shallow ($z_{\text{max}} = 6.8 \text{ m}$) lake on the Yunnan Plateau, China. It is located at $24^{\circ}10' \text{ N}$ lat, $102^{\circ}45' \text{ E}$ long, at an elevation of 1797 m. The watershed/lake ratio is 9.6:1. Lake waters are hard ($\text{Mg} = 3.2 \text{ meq L}^{-1}$, $\text{Ca} = 1.3 \text{ meq L}^{-1}$) and fresh (conductivity = $380 \mu\text{S cm}^{-1}$), and plankton blooms restrict light penetration to less than 40 cm.

An 11-m core was taken in 4.5 m of water. The ^{14}C age at the base (10.9 m) is 30960 ± 860 . Sediments between 11 m and 6 m are high in percent dry weight (35-57%) and low in total C ($< 6\%$), total S ($< 2 \text{ mg g}^{-1}$), and total N ($< 4 \text{ mg g}^{-1}$). Above 6 m, the dry weight content of sediments declines, and the change is accompanied by an increase in the content of organic and inorganic C, S, and N. The stratigraphic change indicates the Pleistocene-Holocene boundary and yielded a ^{14}C date of 11790 ± 70 at 5.9 m. The climatic shift is marked by a rise in abundance of *Pinus* relative to *Quercus*, and greater relative abundance of the floating-leaved *Alisma*.

Red clays in the uppermost 80 cm of the section differ markedly from the Holocene sediments below. The topmost deposits are high in percent dry weight, and have low concentrations of total C, S, and N. Fe_2O_3 and Al_2O_3 comprise about one-third of the sediment dry weight. The sediment geochemistry, combined with lower pollen concentrations in the upper 80 cm, indicates rapid inorganic sedimentation, perhaps as a consequence of near-shore disturbances or water level fluctuations. A ten-fold increase in the riparian human population since the turn of the century suggests that agricultural and construction activities strongly influenced recent deposition.

NATURAL ENVIRONMENT AS REFLECTED IN SEDIMENTARY FACIES AND SPORO - POLLEN
ASSEMBLAGES IN DONGTING BASIN IN QUATERNARY

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Based on the formation of sedimentary facies and the sporopollen Assemblages derived from drilling cores of Huatian and Anyou in the Dongting basin and comparison with other boring profiles of the region, the natural environmental changes of the basin during the Quaternary Period can be summarized as follows:

There are eighteen rhythmic successions of grain size in the Huatian boring profile (Drill Hole Tian 11) and seven rhythmic successions in the Anyou boring profile (Drill Hole Ck. 10). They represent four different sedimentary periods (Q₁, Q₂, Q₃, Q₄). The series of sediments belongs to cyclothems of fluvial facies and reflects that brooklets and lakes interwove here and there on the basin and these water bodies were often wandering in natural. This denotes that the supposed existence of a great lake embracing the entire Dongting basin during the Quaternary Period is inconceivable.

The Huatian boring profile can be subdivided into six vegetational zones in the following ascending order: evergreen broad and deciduous broad-leaved forest, herb-shrubby fern and aquatic plants, needle-leaved and deciduous broad-leaved mixed forest, deciduous broad-leaved forest, deciduous broad and evergreen broad-leaved mixed forest, and herb-shrubby fern (with deciduous broad trees) and aquatic plants, corresponding climatic changes of wet-hot, temperate, cold-temperate, warm, temperate-hot and wet-hot respectively.

From the above-mentioned conditions, it is clear that the world-wide alternate cold and hot climate in the Quaternary Period did not affect the climate of this region as much as of the northern part of China. We hold that this has been due mainly to the continuous uplift of the Qinling Mountains since the Quaternary, preventing the arid-cold flows of Siberian anticyclone from passing southward. In the meantime, owing to the effects of southern China (taking Qinling Mountains as the dividing line), remained humid. In other words, during the glacial and interglacial periods, the climate was less influenced in southern China than in northern.

TAPHONOMY OF DIATOM ASSEMBLAGES IN LAKE SEDIMENTS.

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Loch Fleet, Galloway, S.W. Scotland was an acidified lake. Experimental liming of the lake catchment has produced changes in water quality and a consistently higher pH has been maintained. This has resulted in a marked response of living diatom communities and provided a means of testing some assumptions about the taphonomy of fossil diatom assemblages. The response (community composition, rate of change) of diatom communities to environmental change, the corresponding response of fossil assemblages and the representativity of the diatom fossil record are discussed.

OCCURRENCE AND PRESERVATION OF DIATOMS AND CHRYSOPHYCEAN MICROFOSSILS:
GEOGRAPHICAL COMPARISONS AND IMPLICATIONS FOR QUANTITATIVE ANALYSES

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The occurrence and preservation of diatoms and chrysophycean cysts and scales are compared for three regions in the United States: California, Florida and New England. Substantial intra-regional and inter-regional variability is found. In California, all three groups are well preserved, and both diatoms and cysts are abundant and diverse. Scales are much more variable (generally rare, occasionally quite abundant). In Florida, all groups occur, but large amounts of debris cause breakage of delicate diatoms and scales especially. Cysts, which are generally more resistant, are less effected. By contrast, in New England scales and diatoms are abundant, diverse and well-preserved. In some lakes, scales are substantially more abundant than diatoms.

The above results have important implications for quantitative paleolimnological studies. For all regions diatoms are most consistently abundant, diverse and well-preserved. The occurrence of chrysophytes is more variable. Thus, it may be relatively difficult to develop regional surficial calibrations for them in some cases (for example, scales in California and cysts in New England). However, their greater variability in occurrence may still provide valuable indications when shifts in total abundance and/or accumulation are associated with disturbance and other changes. Thus, chrysophytes as a whole promise to be valuable bioindicators, but the specific reasons for this vary regionally. Therefore, the nature of siliceous microfossil occurrence and preservation in a given region must be assessed before the best combination of analyses with diatoms and chrysophytes is decided upon.

THE PIRLA PROJECT: RESULTS AFTER FIVE YEARS

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The PIRLA Project (Paleoecological Investigation of Recent Lake Acidification) is a broadly interdisciplinary investigation of the response of low-alkalinity lakes in four regions of the USA to increased atmospheric deposition of strong acids. Questions being addressed are: Have the lakes acidified in recent years? If so, when, how fast, and how much? What are the relative roles of natural processes, land use disturbance, and acidic deposition? Evidence of pH related changes includes diatom (DI) and chrysophyte inferred pH, chironomid and cladocera remains, Ca, Mn, sequentially extracted forms of Al, and historical fish data. The record of atmospheric deposition is provided by Pb, Zn, Cu, V, S, polycyclic aromatic hydrocarbons, coal and oil soot, and magnetic particles. Not all analyses were done for all lakes.

Adirondack Mountains (New York). Analysis of the sediment record of 12 lakes reveals that the 8 clearwater lakes with current pH < 5.5 and alkalinity < 10 ueq/L have acidified recently, beginning between 1920 and 1970. Four of the study lakes were naturally acidic (pre-1850 DI pH < 5.5). The recent acidification is clearly caused by atmospheric deposition of strong acids derived from the combustion of fossil fuels, though other factors may play a role.

Northern New England. The three study lakes all show evidence of recent acidification, though it is relatively slight in two. Acidic deposition appears to play an important role. Analyses of the data are still ongoing.

Northern Great Lakes States. There is no evidence of substantial recent acidification of the study lakes in northern Minnesota, Wisconsin, or Michigan. Some trends of decreased DI pH are observed, but they cannot be clearly related to acidic deposition. One naturally acidic lake (pre-1850 DI pH 4.9) in Michigan, seems not to have experienced a decrease in pH in recent years.

Northern Florida. Four of the six study lakes had pre-1850 DI pH < 5.5. Two lakes have become significantly more acidic recently. Possible causes still being investigated are fluctuations in ground water table and acidic deposition.

In addition to the information on acidification trends, the project has made significant contributions to diatom and chrysophyte taxonomy and ecology and development of paleolimnological techniques.

SEQUENTIAL LIPID EXTRACTION FROM RECENT LACUSTRINE SEDIMENT: VALUABLE
BIOMARKERS OF SPECIFIC SOURCE ORGANISMS IN PALEOLIMNOLOGICAL STUDIES.

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Free lipids were isolated from recent sediment of Loch Affric by solvent extraction; hydrolysis of residual sediment, initially with dilute alkali and then with mineral acid, gives two additional bound lipid components.

The distinctive distribution patterns of fatty acids and hydroxyacids, and those of total neutral lipids, in these extracted lipids show that the mode of occurrence contains much information. The molecular compositions of the neutral and acidic fractions obtained from the three lipid extracts were determined by gas chromatography - mass spectrometry. Acidic and neutral free lipids show a dominance of long-chain ($> C_{20}$) compounds characteristic of the wax constituents of higher plants; *n*-alkan-2-ones and α -hydroxyacids may be microbial metabolites of wax constituents. Base hydrolysis liberates C_{16} and C_{18} ω -hydroxyacids occurring widely in the cutins and suberins of higher plants together with higher homologues similar in relative abundance to the corresponding free ω -hydroxyacids. β -Hydroxyacids liberated by acidic hydrolysis show a molecular size range (C_{10} - C_{18}) and abundance of branched chain compounds typically occurring in lipopolysaccharides of Gram-negative bacteria.

SEISMIC STRATIGRAPHY OF WELSH LAKES - PRELIMINARY RESULTS

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Seismic surveys of two Welsh lakes, Glaslyn and Llyn Gwynant, using a pinger acoustic source, showed gasification of 40% of Glaslyn's upper sediment, slumping and a sediment thickness of several metres. The area of thickest sediment is not the deepest part of the lake. Results indicated that Llyn Gwynant has an average sediment thickness of less than a metre. This is a puzzle. If the lake is presumed to have formed at the end of either the Devensian glaciation or the Loch Lomond stadial, then a reasonable assumption (based on sediment thicknesses in nearby Llyn Peris and Padarn, (Elner and Hapley-Wood, 1980)) is that the lake should contain an average sediment thickness of several metres.

A similar survey of Lake Bala has shown gasification and a sediment thickness of at least 30 metres. The seismic stratigraphy is interpreted with the aid of sedimentological investigations of cores from the lake.

Reference: Elner J.K. & Hapley-Wood C.M. (1980). Journal of Ecology, 68, 95-121.

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Chernobyl Cs-134 and Cs-137 in Swedish varved lake sediment

Varved sediment cores were collected from Nylandssjön, a small dimictic headwater lake in northern Sweden during April 1988. One core (N3) was sliced into annual sections for the period 1953-88, whilst a second core (N6) was sliced into seasonal and sub-annual sections concerning the years 1983-88. Radionuclide concentrations in these sediments were determined by gamma spectrometry using an Ortec low background hyperpure germanium well detector.

Both cores show very distinct peaks of Cs-137 and Cs-134 in the 1986 varve. Core inventory figures indicate that 69% of Cs-137 and 76% of Cs-134 in N3 are contained within the 1985-87 varves, whilst in the sub-annually sliced N6 68% of Cs-137 and 68.3% of Cs-134 occurs in the four samples covering 'winter' 1985-86 to the end of 1986.

The presence of Cs-134 in the pre-1986 sediment of both cores indicates that a small amount of Chernobyl-derived caesium is diffusing downward. In core N3 the Cs-134:Cs-137 'Chernobyl ratio' of c0.5 is maintained to a depth of 5.95cm (the 1976 varve) suggesting that the two caesium isotopes are diffusing downward at an equal rate. Below this the ratio decreases, indicating the presence of weapon-testing Cs-137 in the deeper samples. Crude calculations suggest that Chernobyl derived Cs-137 constitutes c95% of the total Cs-137 in the core.

In both cores caesium concentrations in the 1987 samples are higher than all the pre-1986 samples. This suggests a continued input of caesium from the lake catchment and/or remobilization at the mud/water interface.

PALEOLIMNOLOGICAL ASSESSMENT OF RECENT TRENDS IN ADIRONDACK (N.Y.)
LAKES, AS INTERPRETED BY CHRYSOPHYTE ASSEMBLAGES.

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Past paleoecological studies of lake acidification have demonstrated that trends within the past 5-15 years can be detected, and that at least some lakes continue to become more acidic, despite constant or decreasing rates of acid loading. The recent trends in pH were assessed by the analysis of chrysophyte remains in the top 5 cm of sediment cores (sectioned at 0.25 cm intervals) from lakes that were part of the ELS Phase-II and DDRP projects. Trends in these 20 low ANC (ANC<25 μ eq/L) lakes were assessed quantitatively and qualitatively. Qualitatively, by examining changes in abundance of chrysophyte taxa known to correlate closely with pH, and quantitatively by inferring pH and ANC using a variety of predictive techniques. These techniques should help to answer questions such as: Are lakes currently in steady state, or are they continuing to acidify or recover?

VEGETATION CHANGE AND POLLEN RECRUITMENT IN A LOWLAND LAKE CATCHMENT : GROBY POOL,
LEICS. (ENGLAND).

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Lake-based pollen analysis forms a key element in the reconstruction of landscape and vegetation histories. In order to better interpret pollen data from lake sediments studies of modern pollen recruitment have been undertaken by a number of workers. These have highlighted the importance of the streamborne pollen component in those lakes receiving inflows (Peck, 1973, Bonny, 1978). However, there remains a need for studies of contemporary pollen input to be linked directly to sediment-based pollen studies within the same lake basin.

This study investigates the pollen-based vegetation and land use history of a small lake catchment in lowland England. Groby Pool (12 ha.) has a large catchment/lake area ratio (70:1), and mixed catchment land-use including mixed deciduous and conifer woodland, arable and pastoral land. Pollen recruitment under closed and open vegetation cover adjacent to the main inflowing stream is being monitored, along with the total budget of major pollen sources entering the lake. These modern data will be used to aid interpretation of palynological evidence of vegetation and land-use changes in the catchment over the last 500-1000 years, as recorded in sediment cores from the lake.

An independent check on the validity and significance of lake-based pollen data may be provided by historically documented records of catchment land-use. In the British Isles, these records are more comprehensive in the lowland than in the highland zone; unfortunately the distribution of lakes exhibits the reverse pattern. Groby Pool is fortunate in having good documented records of catchment land-use spanning the last 250-300 years and these are used for comparison with the palaeoecological data. In particular it is asked how far contemporary pollen recruitment data help to explain divergences between palaeoecological and documentary records of landscape change.

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THREE CENTURY HISTORY OF ACIDITY OF NEW ENGLAND (U.S.A.) LAKES

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Three hundred year histories of pH and alkalinity (alk) have been inferred from diatom and chrysophyte remains in cores from 12 northern New England (NNE) lakes. The inferences were based on regression equations derived from the relationships in 63 NNE lakes between (1) diatom and chrysophyte remains in deep-water surface sediments and (2) pH and alk of the water column. Multivariate statistical analyses (PCA, DECORANA, CANOCO) of 25 chemical and physical parameters and the biological remains in the 63 lakes indicated that diatom and chrysophyte distributions were most strongly related to pH and alk. For this reason, and because of good regression statistics and the likelihood that the 63 lakes span the full ranges of conditions that occurred in the cored lakes in the past 300 yr, the pH and alk equations were deemed appropriate for paleolimnological inference. We present reconstructions of water column pH and alk, and related sediment chemical stratigraphy for three of the 12 lakes: Mud Pond (pH 4.6, alk = -23 ueq per L) and Little Long Pond (pH 5.8, alk = 5), Maine, and Haystack Pond (pH 4.8, alk = -18), Vermont. The watersheds of these lakes have been undisturbed since ca. 1900. The following results were obtained. Mud P. 1700-1930: inferred pH (IpH) slowly and naturally decreased from 5.5 to 5.2, inferred alk (Ialk) = ca. 0. 1930-1970: more rapid acidification from IpH 5.2 to 4.8. Since 1970: no changes. Little Long P. 1700-1970: IpH 5.9, Ialk = 30-40, no changes. Since 1970: possible acidification. Haystack P. 1700-1920: IpH 5.2, Ialk = ca. 0, no changes. 1920-1950: acidification from IpH 5.2 to 4.8. Since 1950: no changes. The three lakes: responses of diatom and chrysophyte indicator taxa suggest short-term elevated trophic state in response to 19th century (cen) logging. Lead, PAH and soot in sediment indicate that inputs of air pollutants associated with acid emissions began in the 19th cen, decades before the 20th cen acidification. The acidification is most probably due to anthropogenic acid deposition. Mud and Haystack Ponds, the two lakes with most pronounced 20th cen acidification, had zero alk in the 18th and 19th cens. Such extremely acid-sensitive lakes are not typical of northern New England. Results for the other nine lakes are consistent with the above, and will be briefly summarized.

LAKE SEDIMENT RECORDS OF EROSIONAL PROCESSES

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Accumulations of sediment at the beds of lakes (and estuaries and reservoirs) provide partial records of materials transported from the surrounding drainage areas. Physical, chemical, biological and magnetic analyses, with data for accumulation rates, have been used in a range of environmental settings to infer the rate, form, cause and source of erosion. This paper attempts to review these studies from a hydrological perspective, setting sediment studies within a lake-catchment system. The need for long-term erosional records is discussed in terms of the type of erosional data which may be obtained; certain conventional ways of interpreting sediment data are examined in the light of other evidence from the fields of pedology and geomorphology. Alternative approaches to studying long-term erosion are assessed with regard to their cost-effectiveness and their levels of precision and accuracy. Finally, some suggestions are made about how these erosion records may be used to model hydrological, pedological and geomorphological processes, thus linking together long-term and 'contemporary' timescales of process operation.

THE PALAEO LIMNOLOGY OF SALT LAKES---- A REVIEW

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Arid and semi-arid regions abound on the the surface of the globe, and they are characterised by an excess of evaporation over precipitation. Consequently, the lakes in these regions retain saline waters which may be either ephemeral or permanent. Commonly, saline lakes occur in endorheic regions, and therefore may be the repositories of phenomena which affected either part or the entire basin in which they occur. The nature of the paleolimnological record of saline lakes, in many ways, is quite different from that of fresh water lakes, and has to be interpreted differently. Depending on their morphology, size (with respect with the entire catchment) and the climatic type under which they occur, saline lakes can provide very different types of palaeoenvironmental information. One should not ignore either the importance of the local and regional groundwater have on the hydrology, water chemistry, biota and sediment types in saline lakes, as saline lacustrine systems usually act as "groundwater windows". Consequently, lacustrine records have to be interpreted accordingly. Many saline lacustrine systems have been in existence for extremely long periods of time (sometimes even up to 1 to 10^6 years) and thus have the potential to provide palaeoenvironmental information of great interest for the geological and biological evolution of significant areas of the globe. This is particularly important for understanding the evolution of aridity and the effect of everchanging Quaternary climates on the biota and the landscape. As a result of many saline lakes often drying out, their record occasionally consist of major "gaps" due to deflation or of breaks in sedimentation. These cannot be ignored.

Attention will be paid to the multidisciplinary approach that has to be taken when studying the records of saline lakes. In addition, discussion will focus on the type of halobiont biota worthy of interest for palaeolimnologists, and the nature of information these can offer.

**PALAEOLIMNOLOGICAL ASPECTS OF A SHALLOW LATE GLACIAL LAKE IN
SANDY FLANDERS, BELGIUM**

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During the Late Glacial many small mires were formed in Sandy Flanders. Due to their shallowness and groundwater-dependence, these lakes were highly sensitive to environmental changes in their drainage basin and to climatic variations. Although many of the mires were only short-lived, some persisted throughout the whole Late Glacial period. A multidisciplinary study was carried out on the sediments of one such lake, situated near Sint-Andries, Brugge (51°10'06"N, 3°08'48"E).

Here some 2 m of fine sands, calcareous gyttja and (clayey) peat were deposited in a closed depression in the Tertiary substratum. Sedimentology and stable isotope analyses are summarized by Kiden et al. (this volume). In the following we focus particularly on the diatom stratigraphy.

The first scarce diatom remains are found in the sandy Oldest Dryas deposits. The initial assemblage which contains reworked marine-brackish valves and some subaerial taxa is rapidly replaced by one of a more local origin indicating base-rich, wet-subaerial to aquatic conditions (*Mastogloia grevillei*, *Rhopalodia operculata*). As the water level rises further it gives way to a *Fragilaria* s.l.-*Mastogloia* assemblage.

At the onset of the warm Bølling period the *Fragilaria* dominance wanes and a diverse assemblage with *Mastogloia smithii* var. *lacustris*, *Denticula kuetzingii*, *Cymbellas* and tychoplanktonic *Cyclotellas* develops.

The short Older Dryas event is characterized by very low valve concentrations.

The diatom record becomes discontinuous in the Allerød deposits. Barren zones alternate with layers containing assemblages of different composition. Already in the second half of the Allerød a marked *Fragilaria*-dominance (*F. elliptica*, *F. pinnata*, *F. construens* + var. *venter*) is observed, coinciding with the climatic deterioration inferred from pollen and isotope data.

The predominance of *Fragilaria* persists throughout the Younger Dryas, with a minor interruption at the onset of peat formation. In the uppermost part of the sequence the transition to drier conditions close to the beginning of the Holocene is recorded.

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ACIDIFICATION AND RECOVERY OF BABY LAKE, SUDBURY, ONTARIO, CANADA

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In the Sudbury region lake acidification has remained a major environmental problem. Although several studies have documented acidification in lakes as a result of metal mining and smelting activities, there is paleolimnological evidence that the lakes may be recovering due to reduction in SO₂ emissions (Dixit et al. 1989).

In this study we examine the acidification and recovery of Baby Lake by stratigraphic analysis of diatoms and chrysophytes. Baby Lake is located southwest of Conistan Smelter (~1 km) in the Conistan Valley near Sudbury. The operation of the Conistan Smelter from 1913 to 1972 resulted in acidification of the lake to a pH of 4.2. After the shut down of the smelter in 1972 there was a remarkable recovery in the lakewater pH (1987 measured pH 6.5). The lakewater pH recovery has been closely mirrored by the shifts in the diatom and chrysophyte species composition and inferred pH. The pH inferences were made using the equations derived from the canonical correspondence analysis of algal microfossils in 72 Sudbury lakes.

Reference: Dixit S.S., Dixit A.S. and Smol, J.P. 1989. Lake acidification recovery can be monitored using chrysophycean microfossils. Can. J. Fish and Aquat. Sci. (in press).

THE ROLE OF NUTRIENTS IN REGULATING ALGAL MICROFOSSIL ASSEMBLAGES IN POORLY BUFFERED LAKES

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In the absence of past limnological data paleolimnological approaches have been extensively used to infer past lakewater pH changes. The techniques are based on the observations of the surface sediment microfossil studies where pH was found to be the most important variable influencing diatom and chrysophyte assemblages. Diatoms and chrysophytes are known to be good indicators of lake trophic status, but little is known about the influence of nutrients on these assemblages when pH is most dominant variable.

The Sudbury region contains several manipulated lakes with long-term limnological data (=17 years). In this study we studied 3 manipulated (limed and/or fertilized) lakes (Mountaintop, Middle, and Labelle) to examine the influence of nutrients in controlling siliceous algal assemblages in poorly buffered lakes. All three lakes were manipulated by the Ontario Ministry of the Environment. The pH of Middle Lake was about 4.4 in 1973, after which it was limed and its pH raised to its present value of 7. This lake was also fertilized in 1975 and 1976. The pH of Mountaintop was about 4.6 prior to fertilization and it remained low (4.7 in 1987) after the lake was fertilized in 1977. Lake Labelle was a reference lake. The lake is not very acidic (pH = 6) nor do records indicate any recent acidification, but it was fertilized in 1977. ²¹⁰Pb analysis of cores suggests that at least 2 cm of sediment has been accumulated since the lakes were manipulated. In order to detect these changes the upper portion of the cores were sectioned in fine intervals (0.25 cm). Our study elucidates how diatoms and chrysophytes respond to nutrient inputs in acidic and non-acidic lakes. How important are nutrient changes in determining the size and composition of siliceous algal communities in acidic lakes? Do changes occur only when pH is raised?

SILICEOUS TESTATE AMOEBAE FROM FINNISH LAKE SEDIMENTS

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The freshwater testate amoebae represent a group of interesting microfossils that can reveal much about the catchment and history of a lake. The unicellular organism lives within a test (shell) that it has constructed either from ingested particles (e.g., sand grains, diatom frustules) or from intrinsically formed siliceous plates. In the latter case the organism is covered with overlapping plates that are held together with an organic cement. Death of the organism results in the rapid dissolution of this cement and the individual disassociated plates remain loose within the sediments of the lake. Classification of these Rhizopods is generally based upon the morphological characteristics of the intact test; however, as we have previously shown (Douglas and Smol, 1987), it is possible to identify some of the individual siliceous plates to the generic and sometimes even to the species level. This new microfossil provides additional information about a lake and its catchment area that complements the diatom, chrysophycean and animal microfossil data. We have observed plates from arctic, temperate and tropical regions. Moreover they provide important information about the ontogeny and natural acidification of a lake as the development of peatland vegetation within a lake's catchment can be detected in the fossil record.

An on-going study of approximately 160 lakes from eastern Finland has examined the animal and algal microfossils from these lakes. Our study is examining the siliceous fossil plates from these lakes. High concentrations of these rhizopods are found in lakes draining Sphagnum and other peatland vegetation. The relationship of catchment and percent peatland within the catchment is examined.

Douglas, M.S.V. and J.P. Smol. 1987. Siliceous protozoan plates in lake sediments. *Hydrobiologia* 154:13-23.

CHRYSTOPHYCEAN STOMATOCYSTS FROM ELLESMERE I., CANADIAN HIGH
ARCTIC

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Chrysophycean stomatocysts from Ellesmere I., N.W.T., Canada, were described according to the guidelines of the International Statospore Working Group. The stomatocysts were present in samples collected during the summer of 1986 from small pools, and represent a number of microhabitats (rock scrapings, sediment grabs, open water samples, etc). The flora was dominated by spherical unornamented cysts, although a wide variety of ornamented forms were also present. Cyst degradation was common, possibly as a result of the short growing season and the amplified physical erosion often experienced at this latitude. Cyst distribution according to habitat is also described, and the flora is compared with those described from temperate and mid-arctic regions. This information should be applicable to paleolimnological investigations incorporating stomatocysts.

ATMOSPHERIC DEPOSITION AND DIAGENESIS OF ANTHROPOGENIC ORGANIC COMPOUNDS
IN BOG AND LAKE SEDIMENTS

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Atmospheric transport of organic contaminants from source regions and subsequent deposition to land and water receptors is the most important pathway for global distribution of anthropogenic organic compounds. Methods used to determine spatial and temporal distributions of atmospheric contaminants include measurement of their concentrations in precipitation and air, analysis of dated lake and peat sediment cores and the application of the mass balance paradigm to remote and large lakes. Our strategy to assess the temporal and spatial trends in the atmospheric deposition of high molecular weight chlorinated hydrocarbons (and to a lesser extent PAHs) involves the collection and analysis of dated *Sphagnum* peat cores from bogs across the mid-latitudes of eastern North America. Peat cores represent a nearly ideal setting for such an investigation since they are ombrotrophic, deriving all their input from atmosphere, are isolated from groundwater and surface water flow and have an organic matrix (>90% OC). This latter property enhances the sorption and retention of organic compounds. The environmental millieu minimizes diagenetic processing of these organic compounds. Our studies have led to the construction of atmospheric source (input) functions, and spatial and temporal atmospheric fluxes for organic chemicals including PCBs, DDT and metabolites, HCB and toxaphene. Atmospheric fluxes estimated from peat cores are in agreement with recently measured rain inputs. The shape and the magnitude of the atmospheric signal is compared to dated sediment cores collected in the North American Great Lakes and analyzed for these same chemicals. In general, the atmospheric signal derived from the peat cores agrees with the chronology of organic chemical accumulation in lake sediment cores for the atmospherically-driven (Superior) and the riverine-driven lakes (Ontario). The general agreement in the shape of the source and accumulation functions across the mid-latitudes of North America support a close relationship between the major terrestrial, water and atmospheric reservoirs. This hypothesis will be examined further in the conference presentation.

ACCURACY PARAMETERS IN ALPHA SPECTROMETRY FOR LEAD-210 STUDIES

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Various laboratory techniques have been utilized by different laboratories for measuring lead-210 through polonium-210 alpha counting. Isotope dilution alpha spectrometry of polonium-210 provides a suitable tool for absolute determination of lead-210 in aquatic deposits. Apart from some limitations, alpha spectrometry provides some control parameters "speciation" which could be used to solve depositional anomalies and to evaluate the supported lead-210, Ra-226 and mobile fractions in aquatic systems.

Isotope dilution alpha spectrometry has, during a long period of time (1977-1989), been critically evaluated using different aquatic deposits. Our results show that material type/size, organic content, radiochemical extraction-procedures and physical measuring conditions are important factors influencing lead-210 determinations using alpha spectrometry. Optimization of these parameters is of prime importance in order to achieve economic and accurate results especially in samples with low lead-210 concentrations or small sizes.

LEAD-210 AS ATMOSPHERIC AND NON-ATMOSPHERIC INDICATOR OF
FRESH-WATER LAKE PROCESSES.

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Inland forest lakes from Sweden with minor disturbances from drainage areas and low sedimentation rates show that internal processes limit the utility of single cores from such lakes to mirror atmospheric records of Pb-210 and heavy metals. However, land-use activities cause major destruction of atmospheric records as demonstrated by unprotected lakes with high sedimentation rates. Historical studies of atmospheric and non-atmospheric changes require careful examination of at least two cores, from the same lake, with independent chronological tools.

Swedish lakes with high (unprotected) and low (protected) sedimentation rates have been utilized to evaluate the utility of lead-210 in tracing lake depositional processes. Protected and unprotected refer to land-use activities and direct discharge from point pollution sources. Furthermore, these lakes were compared and the internal and external processes influencing lead-210 concentrations/fluxes are evaluated. Cs-137 and speciation analyses have been used to explore anomalies arising from Ra-226 and land-use activities.

A tale of Holocene testate amoebae in two European lakes

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The two lakes are a contrast. Ullswater in northern England is a large (18 km), glacially deepened basin (63 m) whose catchment is largely deforested. Lago di Ganna in northern Italy is a small (0.4 km), shallow (2 m) moraine lake whose surrounding slopes are populated with chesnut and oak. Histories of the two lakes, as reconstructed from pollen, macrofossil and diatom studies, are confirmed and supplemented by the Holocene assemblages of testate amoebae in a 5.4-m core from Ullswater and a 11.6-m core from Lago di Ganna.

In both lakes, testates are absent or rare in the lowermost Post-glacial sediments, and earliest faunas are dominated by species of Cyclopyxis and Centropyxis. In Ullswater, further evolution there is characterized by: 1) modest-sized populations of Cyclopyxis, Centropyxis and Diffugia at the onset of Boreal time (ca 10,000 BP), followed by an increase in the size of populations near the beginning of the Atlantic period (ca 7,000 BP); and 2) an increase in numbers of individuals and species of Diffugia, and a decrease in numbers of Cyclopyxis at the end of the Atlantic (ca 5,000 BP). Core-top samples yield small populations of testates ($<1,500 \text{ g}^{-1}$), including Arcella.

In Lago di Ganna, the chronology of testates is shorter. Testates occur rarely in lower Atlantic and Older Dryas silts, and Cyclopyxis and Centropyxis do not establish permanent lake-bottom communities until the end of the Atlantic. Diffugia succeeds Cyclopyxis as the subdominant form in the gyttja of the lower Subatlantic (ca 1,500 BP). Although the testate assemblages are less diverse, the maximum population densities in Lago di Ganna are 3-4 times larger than those in Ullswater, and core-top populations are very large ($>30,000 \text{ g}^{-1}$).

CHANGES IN SEDIMENT PHOSPHORUS FRACTIONS AND DYNAMICS DURING
8-10,000 YEARS IN TWO OLIGOTROPHIC CLEAR-WATER LAKES IN SOUTH
SWEDEN

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In order to reconstruct and describe the historical development of two oligotrophic clear-water lakes (L. Fiolen and L. Skärsjön) in southern Sweden, sediment cores were taken (5.75 and 5.83 m, respectively). Both lakes are situated in forested areas and in a part of Sweden where most lakes have been acidified by atmospheric deposition.

As a sub-project of the "Oligotrophic clear-water lakes. Past-Present-Future"-project, a special investigation has been addressed to the phosphorus structure and function during the last 8-10,000 years of the development of the lakes.

Sediment phosphorus fractionation (described by Hieltjes and Lijklema 1980) has been made on 117 samples from L. Fiolen and 103 samples from L. Skärsjön. The fractionation method divide the total phosphorus content into labile P, Fe- and Al-bound P, Ca-bound P and organic bound P.

The variation of the four P fractions during different stages of the development of the lakes will be presented and discussed, in relation to variations of some other physical-chemical and biological parameters.

Hieltjes, A.H.M. and L. Lijklema. 1980. J. Environ. Qual. 9:405-407.

EARLY LAKE ONTOGENY FOLLOWING NEOGLACIAL ICE RECESSION AT
GLACIER BAY, ALASKA, USA.

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This study explores the environmental forces controlling lake ontogeny at Glacier Bay as a model for early Holocene lake evolution in north temperate lakes worldwide. Long term chemical and biological changes in lakes are investigated with two complimentary research strategies: (1) limnological conditions are compared among 32 lakes of known age and in different stages of primary catchment succession, and (2) sediment cores from these same lakes are analyzed stratigraphically for fossil diatoms to ascertain developmental trends in pH, alkalinity, algal composition and trophic status at individual sites.

Trends in water chemistry inferred from the chronosequence approach include a progressive loss of alkalinity and dilution of surface waters, an increase in apparent color from organic acids, and a decline in pH. Because of considerable scatter in the chronosequence data, these changes are not apparent until several hundred years after deglaciation. Preliminary observations of biotic trends include an apparent succession of higher aquatic plants mediated by alkalinity changes and a rapid diversification of the diatom flora associated with a proliferation of new growth substrates, particularly macrophytes.

Several hypotheses concerning early postglacial land/water interactions are supported by these results, including (a) the progressive leaching of catchment soils makes lakes more dilute and acidic over time, (b) peat growth and regional paludification impede internal soil drainage and groundwater recharge, causing dilution and eventual dystrophication of surface waters, and (c) hydrologic and geologic differences among sites act to control the rates and direction of limnological change.

Paleolimnological studies of laminated sediments from Shropshire-Cheshire meres, U.K.

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Studies of frozen and soft mud cores from Ellesmere, Rostherne Mere and Berrington Pool, the three deepest of the Shropshire-Cheshire meres of the English Midlands reveal the presence of laminations which are thought to be varves. This hypothesis is being tested by means of fine-resolution diatom analysis after the method of Simola (1977).

Organic geochemical studies of the same sediments show that compounds such as n -alcohols, fatty acids and n -alkanes are all present in sufficient quantities as to form the basis for 'molecular dating', i.e. the ^{14}C dating of specific compounds or groups of compounds of known origin or provenance.

It is hoped that these combined approaches will lead to the development of a method of calibrating both the Holocene radiocarbon time-scale, and the West European calendar of secular paleomagnetic variations, using a varve chronology developed from the laminations in the sediments.

Reference: Simola, H. (1977). Diatom succession in the formation of annually-laminated sediments in Lovojärvi, a small, eutrophicated lake. Ann. Bot. Fenn. 14, 143-148.

Field evaluation of sediment trap performance in a eutrophic
holomictic lake.

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Sediment trapping in lakes can be used to estimate both contemporary sediment accumulation rates and particle sinking rates but sediment resuspension problems can cause considerable overestimates. Resuspension and redeposition cycles are likely to be a major hydrological process in large wind-stressed and relatively shallow lakes such as Lough Neagh in Northern Ireland. The importance of this process is evaluated for Lough Neagh by comparing sediment trapping efficiencies of tubular sediment traps with different aspect ratios (height:diameter) exposed in the lake for time periods ranging from a few days to one year. Sediment trapping results are compared with rates of sediment accumulation measured in sediment cores and by emplacement of stratigraphic markers.

Results show that for traps exposed for one year the sediment accumulation rate measured in those with an aspect ratio $>c.5$ is about ten times that measured in traps with an aspect ratio of <1 . In low aspect ratio traps the annual accumulation of sediment was about 1cm and was similar to the mean rate estimated from sediment cores. The stratigraphic marker indicated a considerably higher rate of sediment accumulation and possibly caused by subsidence of the marker in soft organic lake sediment. The combined results from low aspect ratio traps exposed for shorter time periods show that within-trap sediment resuspension occurs so that per unit time the longer exposed traps collect least sediment. The trapping programme shows that the apparent rate of sediment accumulation measured by tubular traps in this unstratified lake is entirely dependant on aspect ratio (if <5) and on length of exposure. Furthermore, high aspect ratio traps ($>c.5$) overestimate the net rate of sediment accumulation by a factor of 10.

PALHYDAF (PALaeoHYdrology of AFrica). MAJOR RESULTS

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The PALHYDAF programme (1984-1989...) attempts to reconstruct Late Quaternary (130 ka B.P. to Present) environmental and hydrological changes in northwestern Africa, and to interpret them in terms of palaeoclimate.

Lacustrine sequences are collected from closed basins which lie along two meridian transects : Southern Tunisia-Southern Niger, Northern Algeria-Mali. The chronological framework is based on ^{14}C dates (conventional and TAMS methods) and/or Th/U disequilibrium method. Information deduced from the various environmental markers (mineralogy, element chemistry, stable isotopes, biological remains ...) are combined for palaeoenvironmental reconstructions.

Major results already obtained are summarized for individual PALHYDAF sectors : successively : 1) Southern Tunisia ; 1') Northern Algeria ; 2) Southern Algeria ; 3) Northern Niger ; 3') Northern Mali ; 4) Southern Niger.

At the present stage of investigations, the following conclusions can be drawn.

- The last great humid episode observed before the Holocene in Northern Sahara lies *ca* 150-180 ka B.P..
- The existence of a Late Pleistocene humid phase *ca* 20-35 ka B.P. previously admitted is not confirmed in the north Sahara. In all cases, the ^{14}C chronologies obtained for the Late Pleistocene have to be reconsidered by comparison with other dating methods (e.g. Th/U disequilibrium).
- The return of humid conditions at the Holocene occurred before, or close to 10 ka B.P. between 12°N and 28°N.
- In favourable cases, (e.g. Mali), correlations can be made between the chronology of surface palaeohydrology and that of aquifer recharge.
- Quantitative estimates of palaeoclimatic variables (e.g. air humidity) may be attempted by the combined geochemical and palaeobiological approaches.

Once a reliable chronological framework is established and the relative role of the local factors on the environments is estimated, palaeohydrological events can be interpreted in terms of palaeoclimate and integrated in modelling experiments.

THE IMPACT OF URBANISATION
A COMPARATIVE STUDY OF TWO LAKE CATCHMENTS IN COVENTRY

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Chemical, magnetic and palaeoecological analyses have been performed upon sediments retrieved from contrasting lakes within the urban area of Coventry, UK. Wyken Slough is a mining subsidence lake in the northern part of the city which has accumulated some 1.5m of sediment in around 100 years. Within the catchment are to be found a toxic waste disposal site, and an industrial estate which expanded in the 1960's. The impact of these two developments is evidenced by the rapid increase in Cd and other heavy metals levels in the upper lake sediments. Due to additional contributions from urban storm runoff and livestock farming in other parts of the basin, the lake is also experiencing eutrophication as evidenced by the sediment based phosphorus record.

Swanswell Pool is an inner city urban lake dating from the 12th century. The sediments exceed 2m in thickness and the lake was isolated from its contributing catchment by canalisation of the inflowing river in the mid 19th century. This period provides a profound change in sedimentation type and pattern. Despite the isolation from inflowing rivers, some 50-70cm of organic rich sediment has accumulated in just over 100 years. Atmospherically derived heavy metals dominate the chemical record. Phosphorus content also increases sharply due to the discharge of hospital waste to the lake.

The implications of redeveloping these lakes has been investigated and results suggest that recovery of both systems in the immediate future would be extremely costly.

Haematite and Goethite in Lake sediments.

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The magnetic properties of lake sediments have been used for dating, core-correlation and sediment source identification. Many recent studies have concentrated on the ferrimagnetic component in the sediment record, since even minute quantities of ferrimagnetic minerals such as magnetite, maghaemite or greigite, will dominate the magnetic signal. In the majority of systems, imperfect antiferromagnetic minerals such as haematite and goethite will be more abundant than the ferrimagnets, but despite this, it is often difficult to confirm their presence, quantify their contribution to the magnetic properties of the sediment or establish which of the two main imperfect antiferromagnets are recorded. The poster will introduce methods for identifying the imperfect antiferromagnetic contribution to the magnetic properties of lake sediment and their sources. These methods involve recording and modelling the acquisition of isothermal remanent magnetisation in high fields (up to 7 Tesla), carrying out stepwise thermal demagnetisation of high the field remanence, and studying the low temperature susceptibility and remanence of samples. One important outcome of the research will be a clearer understanding of past weathering regimes as they are recorded in the magnetic properties of sediment derived from their products.

HOLOCENE SEDIMENTS OF SALINE LAKES IN THE N. GREAT PLAINS,
USA AS RECORDS OF SALINITY, WATER-LEVEL, AND CLIMATIC
FLUCTUATIONS

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Salinity and water level in closed-basin lakes respond to climatic change as a result of climatic control on the hydrologic budget. We are using the stratigraphy of fossil diatoms and the geochemistry of fossil ostracode shells to reconstruct changing paleosalinity and lake level in the Northern Great Plains, North America and hence to assess Holocene climatic fluctuations.

Transfer functions for the reconstruction of salinity from diatom assemblages have been derived from over 65 regional surface-sediment samples. Experimentally derived partitioning coefficients for Mg and Sr in ostracode calcite provide a transfer function for predicting paleosalinity from ostracode stratigraphy. These transfer functions were tested on a short core from Devils Lake, North Dakota, where historical records document water-level and salinity fluctuations for the last 100 years. For both diatoms and ostracodes the reconstructed salinity corresponds well to the known history of the lake. The reconstructions have also been extended to samples covering the entire Holocene and suggest a number of short-term climatic oscillations in the mid-Holocene.

A LATE HOLOCENE RECORD OF LAND-USE HISTORY, SOIL EROSION, LAKE TROPHY AND LAKE-LEVEL FLUCTUATIONS AT LAKE BJARESJO (SOUTH SWEDEN)

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Lake sediments at Lake Bjaresjo cover the last 2700 years BP. They were studied in the context of the "Ystad project: the cultural landscape during 6000 years in Southern Sweden" (Berglund 1988). Lake Bjaresjo was chosen as one of the reference sites for palaeoecological investigations.

^{14}C datings and ^{210}Pb measurements made it possible to establish a reliable chronology for the whole lake-sediment sequence. Pollen analysis provides a detailed record of the land-use history close to the lake since the beginning of Late Bronze Age. Five main periods of land-use expansion may be distinguished: (1) Late Bronze Age, (2) Viking Age, (3) 1650-1700 AD, (4) 1800-1900 AD, (5) 1950-1983 AD. Water-level fluctuations were reconstructed primarily by means of stratigraphical investigations, pollen analysis and plant macrofossil studies. The main palaeohydrological changes may be correlated to regional climatic changes.

Calculation of total sediment yields from the catchment and measurement of magnetic parameters provide a record of soil erosion and sediment source through time. Periods of intensified land-use are usually characterised by increased sediment yields (periods 1, 2, 3, 4) and by high erosion of topsoils (periods 2, 4, 5). Erosion of subsoils occurs during periods of stabilisation (Early Middle Ages) or because of under-soil drainage (19th, 20th cent.).

Diatom analysis and chemical analyses show that eutrophic conditions were prevailing since Late Bronze Age. Periods of strong increase in eutrophication are recorded during the Viking Age and around 1800 and 1950 AD. High values of nitrogen during part of the Iron Age are due to very low water levels and overgrowing of the lake. Very high contents of labile and FeAl-bounded phosphorus are registered in the sediments dated to the Viking Age, and are related to the practice of hemp retting in the lake.

The investigation shows the close relationships between settlement history, land-use, soil erosion, lake trophy, lake level and climate.

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DIATOMS FOR RECONSTRUCTING PALAEOSALINITIES.
EXEMPLE OF NORTH AFRICA

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Correlations are shown between salinity, and diatom species or communities, on the basis of about 100 modern diatom samples from waters of the chloride-sulphate type of the Maghreb., and with salinity ranging from 0,3 to 70‰. Factor Analyses of Correspondence (FAC), Component Factor Analyses (CFA) and Cluster Analyses (CA) are conducted on two independant set of data: diatom percentages, and physico-chemical variables. The coefficient of multiple correlation between salinity and species percentages reaches 0,896. A transfer function is established by calculation of the regression coefficients for 100 characteristic taxa.

An attempt is made for reconstructing palaeosalinities through Late Quaternary profiles from the Northern and Central Sahara (Tunisia , Algeria and Mali), where a multitude of interdunal depressions contain sediments of fresh to hypersaline waterbodies. Fossil and modern ecological conditions are compared by introducing fossil assemblages as passive elements in FAC conducted for modern assemblages, and by using the transfer function. Statistically derived estimations of palaeosalinity can be made for many samples.

Problems remain, however, when no modern analogs of the fossil flora are found at a regional scale. That is for example the case of samples dominated by *Cyclotella caspia*, a "brackish" water form abundant in numerous Holocene Saharan palaeolakes, but unknown today in Africa. Interpretation thus needs comparison with other modern biogeographical zones, e.g. the Northern Great Plains province of North America where this species occurs in high number in meso- to polysaline lakes.

**ENVIRONMENTAL HISTORY OF FRESHWATER LAKES IN THE LARSEMANN HILLS,
ANTARCTICA**

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The Larsemann Hills are a series of rocky peninsulas and islets in Prydz Bay at 69°24'S and 76°20'E. This stretch of coast lies between the Lambert and Polar Record Glaciers, in the west and the Sorsdal Glacier in the east. There is about 200km² of ice free land with well over 200 freshwater lakes spread evenly over the granite and gneiss hills.

The rate of retreat of the ice margin at the end of the last glacial can be estimated from the onset of biological activity in the freshwater lakes of the Larsemann Hills. Cyanobacterial felts abruptly overly coarse sands which are the proglacial sediments moved by glacial bursts; thick sand laminae also occur higher in the lake sediment stratigraphies. The offshore islands such as Kolloy were abandoned by 9500BP, while the present coastline was attained about 4500BP. The Progress Lake - Lake Nella glacial valleys were free of ice by 4000 BP and 3000BP respectively, though the sediment record in each was truncated as a result of erosion by a glacial burst. A relatively steady rate of ice retreat is indicated, around 0.3 ma⁻¹. In contrast the rates of retreat over a similar time period in the nearby Vestfold Hills have been an order of magnitude higher, around 2.2 to 3.0 ma⁻¹, and have been quite variable. Changes in the diatom flora of selected lakes since deglaciation will be described in relation to periodic disturbance by glacial bursts.

SEDIMENT CHARACTERISTICS IN RELATION TO CULTIVATION HISTORY
OF A VARVED LAKE SEDIMENT FROM EASTERN FINLAND

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Cultivation history was studied by means of pollen analysis from the varved sediment of Lake Suurjärvi, near the town of Savonlinna, East Finland. The oldest signs of cultivation were dated to A.D. 600. Direct gradient analysis (CCA) was applied to the data in order to quantify the relationships between sediment characteristics and human disturbance detected by pollen analysis.

The data set analysed with CCA consisted of percentage terrestrial pollen data and three sediment variables: sedimentation rate, loss-on-ignition, age (calendar years), and influx of charcoal particles as a covariable.

Partial correlation coefficient of the first sediment quality axis and the first species axis was 0.75 ($p=0.001$). Highly significant partial correlations were also detected between both sedimentation rate and age and species axis 1. The percentage variance accounted by the environmental variables for the first species axis was 82.1 .

PALAEOLIMNOLOGY OF NEUSIEDLERSEE -II. THE DISTRIBUTION OF NUTRIENTS
AND TRACE METALS

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Using an accurate freeze core technique 18 core samples were taken in the Neusiedlersee (see Löffler in this volume for lake description) reed belt (a large freshwater marsh of 171 km²) and they have been analysed for their nutrient and trace metal content. The geochemical analysis conducted so far comprised the analyses of organic and inorganic carbon, nitrogen, organic and inorganic phosphorus, and the trace metals included both major and minor elements. Depth variations of the distribution pattern of organic carbon, nitrogen, phosphorus in the cores indicate temporal variability of organic matter deposition associated with the frequent dry falling of the lake and the influence of palaeoecological changes associated with the alternation of marine to lacustrine environment in the past. In the tertiary sediment, at some sites the organic phosphorus compartment seems to be completely exhausted, an indication of total biomineralisation. Accordingly there is a parallel decrease in carbon and nitrogen content in the profiles. The highest C,P,N values and trace metal concentrations are recorded in the surface sediments deposited after the drying up of the lake hundred years back.

HISTORICAL DEVELOPMENT (8-10,000 YEARS) OF TWO OLIGOTROPHIC
CLEAR-WATER LAKES IN SOUTH SWEDEN BY CHEMICAL AND DIATOM
INTERPRETATIONS

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In order to reconstruct the historical development of two oligotrophic clear-water lakes (L. Fiolen and L. Skärsjön) in southern Sweden, sediment cores were taken. Physical-chemical and diatom analyses have been performed on cores with a length of 5.75 and 5.83 m. The sediment lithology is a brown fine detritus gyttja. In L. Skärsjön the lower, second part, is more silty and clayey.

Physical and chemical analyses have been made on 117 samples from L. Fiolen and 103 samples from L. Skärsjön. Analysis: density, water-, organic- and carbonate content, total and biogenic silica, total P, labile P, FeAl-P, Ca-P, organic-P, N, S, Na, K, Ca, Mg, Sr, Fe, Mn, Al, Zn, Pb, Cd, Cr, Cu, Ni, Co, Hg, As, W, Se, Bi, B, V, Mo och Ti.

Diatom analysis has been made on 31 samples from L. Fiolen and 32 samples from L. Skärsjön. Results of the diatom analysis show for both lakes a dominance of planktonic forms and fluctuations in the presence of acidophilous-indifferent-alkaliphilous forms. In L. Fiolen the diatom remains from the deepest areas indicate an oligotrophic habitat, becoming nutrient rich between 4.80-4.40 m (around 9,000 B.P.) and verified by the dominance of Aulacoseira italica subsp. subarctica and A. granulata. After that, a slow continuously increase of acidophilous forms occurred, indicated by the disappearance of the Aulacoseira species and an increase in A. distance and the varieties tenella and humilis and A. lirata, and the varieties lacustris and perglabra. The diatom remains in L. Skärsjön showed a different development compared to that in L. Fiolen. L. Skärsjön show less influence of acidophilous forms throughout the whole core, even in the surface sediment. In some areas around the lake the groundwater is buffered when it flows across, and partly also through, a silty, alkaline glaciomarine clay containing some CaCO_3 , before reaching the lake itself.

THE ROLE OF CATCHMENT AREA ON THE TROPHIC STATUS OF TWO SOUTHERN
ONTARIO LAKES (CANADA).

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It has long been recognized that lakes are not functionally isolated microcosms, but rather interact with their watersheds and airsheds through a variety of geological, meteorological, and biological processes. Aquatic productivity is often strongly controlled by watershed processes that regulate erosion and nutrient release. These processes are influenced largely by bedrock and soil types, and catchment vegetation. In this study we investigate the role of the catchment area in determining the trophic status of a lake by comparing sediment cores spanning the post-glacial histories of two lakes. We selected two holomictic, alkaline southern Ontario lakes that are similar in all aspects (i.e. have similar basin morphometry and lake volume, and are from the same geologic and native vegetation zones), but differ widely in the relative sizes of their catchments. The catchment of Flower Round Lake is ten times that of Long Lake. We are currently extending the study to a total of five lakes.

Palynology is used to determine past changes in local vegetation (and provides a time reference), and diatom and chrysophyte assemblages allow inferences of past limnological changes. The two study lakes lie in the same area as a series of calibration lakes which used diatom assemblages to derive equations for a number of trophic variables. It is now possible to employ diatom stratigraphies to quantify the trophic histories of these lakes, at least in terms of chlorophyll *a* concentrations, Secchi depth, and phosphorus and nitrogen concentrations. This enables us to discern the point in the post-glacial history at which the trophic status of these lakes diverged, and allows us to determine the effects of a number of post-glacial events. We are specifically interested in the limnological effects accompanying the shift from a predominantly coniferous to a deciduous forest that occurred in the area about 7,500 B.P., and the effect of the hemlock decline, which occurred 4,800 B.P., on lake-watershed interactions.

RECENT CHANGES TO UPLAND TARNS IN THE ENGLISH LAKE DISTRICT

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Three small lakes near Wastwater, on the western side of Cumbria, occupy adjacent catchments. They lie on Borrowdale Volcanic bedrock and the catchments have shallow, acid - peaty soils supporting a treeless, rough grassland.

Diatom profiles from all three cover the last c. 1000 yrs. However a profile of older sediments in Low Tarn suggest that these sites did not pass through the *Fragilaria*/alkaliphilous sequence commonly found in larger, more lowland lakes but were more acidic throughout the post-glacial.

The profiles, though differing in detail, provide the same broad picture of lakes where the alkalinity has declined in the last two centuries. The deepest site, Scoat Tarn (a typical corrie lake) used to support a *Cyclotella* plankton typical of many local lakes where the pH is currently > 6.0 and alkalinity > 30 µeq/l. Greendale and Low Tarns, being shallower, were dominated by benthic and epiphytic forms. The diatom assemblages indicate a pH decrease of > 1.5 units since the 1850's and there is a definite gradation in onset and severity, with Greendale Tarn the latest and least affected due to buffering by marginally better soils.

The catchments are all small and undisturbed by any changes, other than those of animal grazing. They were not directly downwind of any suitable industry; however, the geochemistry shows there were distinct increases in the amounts of heavy metals deposited from the atmosphere. All three sites show a recent reversal in the pH trend.

Sequential inorganic chemical analysis of a sediment core from Slapton Ley,
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Analysis of the uppermost 40cm of a sediment core from Slapton Ley, based on the fractionation procedure of Engstrom and Wright (1984), allowed the identification and quantification of the authigenic, biogenic, and allogenic components. Lead-210 dating of the same core enabled trends in both concentration (mg g⁻¹), and influx (mg g⁻¹ cm⁻²) to be evaluated, and compared with the recent (last 100a) land-use history of the catchment of the Ley.

Expansions of sedimentary allogenic K, Fe and Al are interpreted as recording increased soil erosion in farmland in the catchment after 1945, a process which appears to have intensified during the 1970s. Similarly, a peak in sedimentary authigenic nitrogen for the period 1977-80 is correlated with a well-documented maximum in inputs of nitrate from the watershed (Burt et al. 1988), which also coincides with a change in the surficial diatom flora (Wilmshurst et al. this volume). Trends in sedimentary authigenic and allogenic phosphorus are less easily accounted for, however.

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THE INFLUENCE OF LAND USE IN THE KYRÖNJOKI DRAINAGE BASIN ON THE
SEDIMENTATION OF THE RIVER DELTA

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The hydrology and sediment load of rivers in Western Finland have greatly changed during recent decades, due to human activities. In the drainage basin of the River Kyrönjoki, the factors having the greatest influence on sedimentation have been agriculture, forestry drainage of peatlands, peat harvesting and watercourse works.

Samples of the sediment surface (0-2 cm) from 66 sites and longer cores (up to 540 cm) from 9 sites in the estuary of the Kyrönjoki were analysed for water content, organic content, C, N, P, Ca, Fe, Mn, Pb, Cu, Zn, Cd and Hg. One core was dated on the basis of annual laminations and another on the basis of change in chemical conditions due to damming in 1957.

The chemical analyses of the cores showed that the organic matter and heavy metal content have increased during recent decades. The heavy metal content was clearly lower than in areas polluted by industrial works. The phosphorus content of the sediment was in many cases very high. The sedimentation rate in the delta increased from the 1930s to 1950. In the 1960s it slightly decreased, and after 1970 it has been below the level of 1930s. The sedimentation rates of organic matter have been fairly stable all through the period measured, even though the organic content has increased.

The increase of organic matter and heavy metal content in the sediment over recent decades is evidently due to the increased intensity of agriculture, forestry and peat harvesting in the drainage basin. Drainage of peatlands in particular has increased erosion and the organic sediment load of the river. Waste-water from towns and villages has caused an increase in the amount of phosphorus. Building of reservoirs after the year 1970 has decreased the sedimentation rates in the delta, but the effect of other watercourse works (clearing of the channel and building of artificial embankments) is not clearly visible in the sediments.

THE LATE QUATERNARY BLUE-GREEN ALGAL RECORD IN LAKES ACROSS
CENTRAL ALBERTA, CANADA

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The Late-Quaternary blue-green algal records, as determined through measurements of myxoxanthophyll and oscillaxanthin concentrations, are presented for five lakes along an approximate west to east transect across central Alberta. Most westerly are two oligotrophic lakes, namely Lorraine Lake (lat. 52° 44'N long. 117° 40'W) a subalpine lake in the Rocky Mountains, and Fairfax Lake (lat. 52° 58'N, long. 116° 34'W), located in the foothills region. In central Alberta data are present for mesotrophic Lake Wabamun (lat. 50° 30' and 50° 35'N, long 114° 26' and 114° 44'W) and eutrophic large but shallow Cooking Lake (lat. 53° 6'N, long. 113° 02'W). In east central Alberta data are presented for eutrophic deep Moore Lake (lat. 54° 30'N, long. 110° 30'W).

Although each lake displays its own individuality with respect to the pigment stratigraphies, maximum levels occurred in the early to mid-Holocene (10,000 to 5000 yr. B.P.). Lower and more consistent values characterize the last 5000 years. Superimposed upon these general trends, related to changing climate, are individual lake responses. For example, in Moore Lake massive peaks occur at ca 4470 yr. B.P. corresponding to rising lake levels, decreased salinity, and presumable increased nutrient input. Initially, low pigment concentrations in Cooking Lake maybe due to high erosional and catchment region instability.

Members of the Oscillatoriaceae, as determined through measurement of oscillaxanthin concentrations, were invariably the pioneering blue-green algae. In all but Moore and Lorraine lakes, except for the initial stages, oscillaxanthin concentrations generally exceeded those of myxoxanthophyll. In Moore Lake phytoplankton blue-green algal populations dominated but in Lorraine Lake benthic blue-green algae probably dominated throughout the core.

Lake Sediments Can Tell Us About The History of Air Pollution. Ronald A. Hites, School of Public and Environmental Affairs and Department of Chemistry, Indiana University, Bloomington, Indiana, 47405.

Numerous air pollutants are generated from combustion sources and are transported over long distances. These pollutants are removed from the atmosphere by various processes and deposited onto land and water. Those pollutants deposited on or very near lake surfaces eventually find their way to the lake's sediment where they are accumulated. If the sediment is not well mixed, a sediment core will give historical information on atmospheric deposition. This, in turn, can help one deduce the sources of the pollutants. Work from our laboratory on three classes of compounds will be presented. Polycyclic aromatic hydrocarbons (PAH) are the result of the incomplete combustion of almost all fuels. We have studied their accumulation in sediments from Siskiwit Lake on Isle Royale, which is in Lake Superior (United States). These studies resulted in quantitative information on PAH deposition velocities and on their mass transfer coefficient from the lake to the atmosphere. We have also studied certain fluorinated aromatic compounds coming from a dump site in the city of Niagara Falls, New York. These studies have allowed us to follow the movement of particle adsorbed pollutants throughout Lake Ontario. Other studies on polychlorinated dioxins and dibenzofurans have led to the conclusion that these compounds result from the anthropogenic combustion of chlorinated organic compounds (primarily in municipal incinerators and in automobile engines). We were able to link lake sediment studies to atmospheric concentrations using the deposition velocity calculated above for PAH. It is quite clear from these three studies that measuring the historical record of organic pollutants in lake sediments is an excellent method for determining the past history of air pollution, information which would otherwise not be available.

WEICHSELIAN CHIRONOMID AND CLADOCERAN ASSEMBLAGES FROM MAAR
LAKES

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Sediments from maar lakes in the periglacial area were analysed to obtain information about the limnetic fauna of Pleniglacial lakes. The lakes studied were Meerfelder Maar, Holzmaar, and Schalkenmehrener Maar (Eifel, FRG) and Lac du Bouchet (Massif Central, France).

The Upper Pleniglacial was characterized by extremely low abundances of cladoceran and chironomid remains. In all the lakes the chironomid taxa *Diamesa*, *Protonypus*, *Micropsectra* and *Paracladopelma* were predominating during this period. The occurrence of the genus *Diamesa* the species of which are typical of running waters seems to be a peculiarity of this period.

The core from the Lac du Bouchet obviously covered the entire Weichselian period. In the Middle/Lower Pleniglacial and Early Glacial abundances of remains varied but were mostly significantly higher than in the Upper Pleniglacial. The Cladocera were almost exclusively represented by two species, *Alona quadrangularis* and *Chydorus sphaericus*, which exhibited long term alternations of predominance.

Micropsectra, *Tanytarsus*, *Paratanytarsus*, and *Paracladius* were the most abundant chironomid taxa of this period. In the chironomids there were also long term successions mainly produced by shifts in frequency of *Micropsectra* and *Paracladius*.

A shift within the cladoceran assemblage in the lowermost section of the core indicated a warmer climate. These sediments possibly originated from the Eem Interglacial.

PRELIMINARY REPORT ON MULTI-CHANNEL REFLECTION RESEARCH FOR
ANCIENT BIWA GROUP UNDERNEATH THE SETO INLAND SEA MARINE SEDIMENTS

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Our present tasks after the work of deep drilling (for three million years) in the center of Lake Biwa are 1) to reconstruct limnetic succession for five million years - three million years ago since the birth of Lake Biwa 2) to trace former extension of Lake Biwa towards the mainland of China from which many fresh-water fishes and molluscs had moved to Lake Biwa.

In order to find the clue for subject No. 2 above, multi-channel reflection survey has been carried out in February 1989 in Seto Inland Sea. We expect to obtain sediment nature and may start another deep drilling in order to get proof on existence or non-existence of Ancient Lake Biwa Group underneath the present marine sediments of the Inland Sea.

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A combined mineral magnetic and radiometric approach to sediment source determination in the catchment of Howden Reservoir, Derbyshire, UK.

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In an investigation of the dominant sources of sediment supply to Howden Reservoir, and the geomorphic processes operating in its catchment, a combined strategy has been employed. Both the mineral magnetic properties of soils, substrates and sediments and their radiometric characteristics have been utilised to try to establish linkages between the reservoir's sediment and source.

The catchment comprises the headwaters of the upper river Derwent in the Peak District National Park. It lies at the southern tip of the Pennines; an area renowned for upland peat erosion. Consequently a high rate of sedimentation in this c75 year old impoundment is to be expected.

The catchment's broad flat interfluvies and steep sided valleys have been sampled and material taken from potential sediment supply sites around the reservoir's margins and along its tributaries. Similarly comprehensive sampling of deposits in the reservoir has also been undertaken. Then not only were mineral magnetic measurements of the collected materials made, but representative samples were also subjected to radiometric analysis.

This is an environment where the use of any one single technique in sediment source determination has proven to be inadequate. However, when a combined and integrated approach is applied, a clearer insight into the processes at work in the catchment begins to emerge.

CHERNOBYL RADIOISOTOPES IN LAKE-WATERSHED SYSTEMS
IN GALLOWAY, S.W. SCOTLAND

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The accident at Chernobyl in April, 1986 introduced into the environment a well-defined spike of radioactivity. It has provided a unique opportunity to evaluate the behaviour of radionuclides in soils, peats and sediments.

Freshwater sediments are potentially important sinks for radioisotopes deposited on land and water surfaces. Besides direct deposition, much of the radioactivity that enters surface waters may be transported by run-off from the catchment. The timing and relative amounts of the radioisotopes entering lakes can be monitored by determining the concentrations and inventories of radionuclides in lake sediment cores and catchment soils sampled at regular intervals. We have adopted such a lake-watershed approach in two lake catchments in the high Chernobyl deposition area of Galloway, S.W. Scotland. The aims are to evaluate the potential use of Chernobyl fallout in :

- (i) Monitoring lake sediment accumulation rates
- (ii) Tracing particle or solute movement as part of slope process and erosion/sediment source studies.

The lakes/catchments under detailed study are Loch Dee and Loch Fleet. Additional lochs in the area are also being monitored (Round Loch of Glenhead and Loch Grannoch). Lake sediment cores from each of the lakes were obtained in 1986, 1987 and 1988, with peat and soil cores from the catchments of Loch Dee and Loch Fleet sampled in 1986 and 1987. Samples of suspended sediment trapped over a one year period (1987-1988) in Loch Fleet have also been analysed.

The results presented show the concentration profiles and deposition inventories of Cs-137 and Cs-134 for pre-Chernobyl (where available), 1986, 1987 and 1988 sampled lake and catchment cores.

HEAVY METALS IN RECENT SEDIMENTS OF LLANGORSE LAKE, WALES: NON-FERROUS SMELTING, NAPOLEON AND THE PRICE OF WHEAT - A PALAEOECOLOGICAL STUDY

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Elevated concentrations of heavy metals (Cu, Pb, Zn) have been found in the upper part of sediment cores collected from Llangorse Lake, in south-central Wales. Palaeomagnetic evidence from one of the cores and ²¹⁰Pb analysis of another core suggest that the increase in sediment metal concentrations began during the eighteenth century. A sharp increase in the concentrations of Cu, Pb, and Zn in the sediment profile appears to have occurred during the latter part of the eighteenth century. Metal concentrations remained high until the mid to latter part of the nineteenth century.

There are no known ore deposits or heavy industry in the lake catchment. However, 50 miles up-wind, in the Swansea region, was a major non-ferrous smelting industry. This industry underwent substantial expansion in response to demands for metals during the Industrial Revolution. Pollution controls were minimal. Thus it is likely that emissions from this industry were carried on prevailing winds and deposited onto the lake catchment.

Evidence from agricultural crop returns indicates a significant increase in the amount of land devoted to tillage in the catchment, particularly to cereal production, during the late eighteenth and first half of the nineteenth century. In part, this may be related to increased demand for home-grown wheat during the Napoleonic Wars. This agricultural shift appears to correlate with increased concentrations of heavy metals in the lake sediments. Pollen evidence from the lake sediments also suggests increased agricultural activity in the catchment at this time, whilst diatom evidence suggests increased turbidity of the lake waters. It is suggested that the heavy-metal burden to the sediments increased, probably because soils, contaminated for many years with metals by long-range aerial transport from the Swansea area, were then ploughed, disturbed, and transported into the lake by catchment run-off.

This hypothesis may be taken further, to provide an explanation for a subsequent fall in metal concentrations in the sediment profile. This fall appears to correlate with the decline, due to overseas competition, of the non-ferrous smelting industry and to contraction of the acreage of tilled land in the catchment related to the agricultural depression in Britain during the later decades of the nineteenth century.

The concentration of metals in the sediment profile later increases, a common feature of many lake sediments laid down in the twentieth century.

SEDIMENTS AND STABLE ISOTOPE STRATIGRAPHY OF LATE GLACIAL SHALLOW
LAKES IN SANDY FLANDERS (BELGIUM)

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During the Late Glacial, a number of small, shallow (up to 2 deep) closed depressions existed in Sandy Flanders. They were almost completely infilled with calcareous and organic sediments by the end of the Late Glacial. Due to the rapid response of these small basins to environmental changes they are believed to be well-suited for palaeoecological and -climatic research.

As an example the results are summarized of sedimentological studies and isotope analysis ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$) of the infilling of a small lake near Sint-Andries, Brugge (51°10'06"N, 3°08'48"E). The stratigraphic framework was provided by radiocarbon datings and pollen analysis, while the study of diatom remains (Denys et al., this volume) yielded data on palaeolimnology as well as an independent control of some isotope results.

The Oldest Dryas is characterized by deposition of sandy and silty material. The carbonate content is too low to yield reliable stable isotope results.

During the Bølling carbonate precipitation increased markedly. From the isotope data ($\delta^{13}\text{C}$) a relatively large freshwater input and low evaporation may be assumed.

The subsequent Older Dryas period is marked by an important decline of the $\delta^{18}\text{O}$ -content which can be attributed to significantly lower (summer) temperatures. Although this cold event apparently did not last longer than about 100 years, its effect is recognizable in the pollen record as a decrease of the AP-percentage.

At the start of the Allerød both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values increase strongly, suggesting a considerable rise of temperature. The high $\delta^{13}\text{C}$ -content points to equilibrium conditions with atmospheric CO_2 due to high evaporation. Likewise, the large $\delta^{18}\text{O}$ values may at least be partly explained by evaporative enrichment. Nevertheless, these results indicate relatively warm and/or dry conditions during the Allerød. The carbonate content also reaches a maximum in this period.

The Allerød-Younger Dryas transition is characterized by a sharp decline of both isotope curves and of the carbonate content of the sediment. An abrupt change from calcareous gyttja to peat occurs at this time. During the rest of the Younger Dryas a rather homogeneous clayey-silty peat is deposited under cold conditions.

PALEOLIMNOLOGY OF A POLAR OASIS, TRUELOVE LOWLAND,
DEVON ISLAND, N.W.T., CANADA

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Sediment cores from the larger, deeper lakes in Truelove Lowland (75° 40'N, 84° 35'W), an area of exceptional biological diversity in the Canadian High Arctic, have been analyzed for diatoms and chemical composition. Diatoms together with allochthonous and autochthonous chemical components in the sediments have been used to reconstruct changes in paleoenvironmental conditions. Lake formation began approximately 10 600 years ago as a result of glacio-isostatic uplift that progressively isolated a series of shallow marine lagoons. Based on the presence of distinctive diatom assemblages, stratigraphic zones in the sediments are identified as a basal marine zone, an intermediate and transitional brackish/marine zone and an upper freshwater zone.

Following isolation from the sea, the lakes were flushed with freshwater produced by snow and ice melt. The period of transition from marine to freshwater conditions varies according to the present elevation of the lake and has been strongly influenced by the rate of glacio-isostatic rebound at the time of isolation. Specific chemical elements are sensitive indicators of changes in environmental conditions, both within the lakes and their catchments. Fe, Cr, and Mo in the sediments are associated with the isolation phase when lake sedimentation is sensitive to the presence of brackish water and erosion within the catchment. Lake isolation also appears to be associated with the development of ephemeral hypolimnetic anoxia leading to the precipitation of Mo as MoS_2 .

During the early post-isolation phase in the Lowland the response of lake biota to an influx of nutrients is reflected in an increase in biogenic silica and organic carbon in the lake sediments. However, throughout the Holocene the lakes have remained oligotrophic and lake sedimentation has been dominated by variations in non-biogenic factors. Over time the progressive stabilization of surface materials and pedogenesis within the lake catchments has been marked by decreasing Cr, As, and Na in the sediments and an increase in allochthonous Mn and Fe and bear testament to the relative resilience of this tundra biome.

INFERENCE OF MULTIPLE ENVIRONMENTAL PARAMETERS FROM
ACIDIFICATION STUDY LAKES: PIRLA PROJECT, NORTH AMERICA

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Paleolimnological inferences of lakewater pH have been made using diatoms in sediment core assemblages for over 30 years, and the basis of calibration functions has evolved from relatively subjective index values to multiple regression of pH categories to the present inferences based on more objective estimates of species optima along the pH gradient. Paralleling the statistical advances, major strides have been made in the major biological issue affecting reconstructions: systematic description of the organisms. Two of the largest programs investigating lake acidification (PIRLA and SWAP) have taken matters a step further by coordinating methods and taxonomic harmonization so that regional data sets can be compared with confidence. Lake acidification paleolimnology has become increasingly multi-disciplinary, and transfer functions are now often based on diatoms and chrysophytes (Charles and Smol 1988).

Weighted averaging calibration and reconstruction are the most reliable inference techniques currently available (ter Braak and Prentice, 1988), following on the heels of canonical correspondence analysis ordination (ter Braak 1986). We have used diatom and chrysophyte assemblages from sediment cores in lakes sensitive to strong acid deposition in 4 North American regions to infer past lakewater pH, total alkalinity, dissolved organic carbon, and total aluminum. Lakewater pH is usually the strongest environmental parameter in terms of explaining variance of the microfossil data, and alkalinity is similar but not quite as strong. Dissolved organic carbon is weaker, but it varies in strength among regional data sets depending on how well that gradient is represented in the calibration lakes. Aluminum is a metal that can be toxic to biota throughout the trophic web, and we have had some success in reconstructing past concentrations.

Investigators in charge of various PIRLA1 regional data sets are: D.F. Charles and D.R. Whitehead, Adirondack Mountains; R.B. Davis, S.A. Norton, and J. Ford, New England; J.C. Kingston and R.B. Cook, northern Great Lakes states; P.R. Sweets and T.L. Crisman, northern Florida. The PIRLA2 data are the responsibility of J.P. Smol, J.C. Kingston, S.S. Dixit, K.E. Camburn, B.F. Cumming, and A. Uutala.

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HYDROSERAL DEVELOPMENT OF THE KOTASUO BOG, SOUTHERN FINLAND,
STUDIED BY DIFFERENT BIOSTRATIGRAPHICAL METHODS

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A hydrosere from open water to mire was studied in the basin of Kotasuo bog, Southern Finland (Fig. 1), using pollen, diatoms, cladocerans, macrosubfossils and ^{14}C -datings. The development of the bog itself has formerly been described by Korhola (1988).

According to the pollen analysis the limnic sediments of the bog basin were deposited during the Birch-alder-hazel-elm Zone of Southern Finland, corresponding to the atlantic and partly subboreal chronozones of Norden (Fig 2). The basin was isolated from the ancient Baltic Sea during the Ancyclus "lake" stage, more than 8000 BP, as indicated of the change in diatom flora at a depth of 900-940 cm (Fig 3). After isolation the sedimentation rate was at first rapid ($> 2 \text{ mm/y}$), becoming afterwards more slow (0.5-0.8 mm/y) until the final terrestrialization, which seems to have happened extremely fast (Fig. 4).

The planktonic Bosmina-species were dominant cladocerans at the beginning of a lake stage (Figs 5 and 6). At a depth of 750 cm (about 7500 BP) the planktonic taxa are replaced by littoral fauna, especially by Chydorus sphaericus. This together with Leydigia spp., Pediastrum-algae and Nitzschia scalaris indicates an enrichment of nutrients and electrolytes of water. The transition from planktonic Cladocera to littoral species coincides with a change in lithostratigraphy, suggesting a development from a more or less deep open water-body to a more shallow lake. At a depth of 650 cm (about 5700 BP) the Cladocera-species adapted to more dystrophic conditions (Alona spp., Alonella spp, Fig 5) begun to rise, indicating a shallow water body with a high content of organics and nutrients. Seeds, remains and pollen of submerged and floating-leaved aquatic macrophytes are found from this level upwards (Fig. 2 and Table 1). The amount of organic matter of sediment rises rapidly on the upper part of the sediment column (Fig. 2). Typha latifolia, Phragmites australis and Equisetum fluviatile were the main species that contributed to filling-in of the basin and succession to a reedswamp. The fen-element, however, occupied rapidly space and the basin became a luxurious fen with many different Cyperaceae (Table 1). The first stages of a mire development were very short in duration, and the natural oligotrophication and progressive development changed the mire into a bog. Reference: Korhola, A. (1988). Suo 39(4):73-89.

POLLEN AND DIATOM EVIDENCE FOR VEGETATION AND LAKE-LEVEL CHANGE SINCE 18,000 BP AT TIGALMAMINE, MIDDLE ATLAS, MOROCCO.

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Pollen, diatom and sedimentological analyses of two radiocarbon-dated cores of calcareous lake sediments from the Middle Atlas mountains, Morocco, provide an 18,000-year record of change in lake level and local vegetation, attributable to climatic and anthropogenic causes. From 18,000 to 16,300 BP, a shallow marsh was present at the bottom of a steep-sided doline; the catchment was vegetated by steppe grassland. From 16,300 to 9000 BP, deeper water (1-2m?) prevailed, except for a drier episode from 13,000 to 12,000 BP. Quercus rotundifolia Lam. colonised the area at 14,000 BP, but declined at 12,000. Oak forest, this time including Q. canariensis Willd, replaced the grassland 8500 years ago, following a substantial rise in lake level. Cedrus atlantica (Endl.) Carrière arrived in the area about 4000 years ago. Brief shallow-water episodes are shown by diatom evidence at 7300-6850 BP and at 3500BP, but are not apparent from the pollen data, possibly because they represent temporary drainage through karstic conduits rather than climate change. Anthropogenic forest degradation dates from 2500 B.P. In spite of this, the Cedrus forests became more vigorous about 450 years ago.

ROADING-BUILDING, HYPOLIMNETIC AERATION, LIMING AND FOOD-WEB
MANIPULATION: THE ANNUAL RECORD OF FOSSIL PIGMENTS.

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Carotenoid and chlorophyll profiles in annually-laminated sediments were compared with effects of watershed disturbance and experimental lake manipulation in dystrophic Tuesday Lake, Michigan, USA. Pigment stratigraphies were also compared with those of reference and manipulated systems which lie 0.5 km distant.

Concurrent with road-building activities (1951), concentrations of pigments indicative of green algae (β -carotene, lutein-zeaxanthin, chl b, pheophytin b) increased while those of cryptophytes (alloxanthin) and the Chrysophyta (fucoxanthin, chl c) did not. Hypolimnetic aeration (1956) was signalled by reductions in the abundance of all chlorophyte pigments.

In 1961, hydrated lime was added and rainbow trout (*Oncorhynchus mykiss*) were stocked to the minnow-dominated waters. Increased water clarity was paralleled by short-term increases in pigments characteristic of the Chrysophyta, similar to those in other lime-manipulated lakes in this region. Concurrent with trout addition, *Daphnia rosea* and *D. pulex* remains reached their highest abundance in the core and concentrations of the grazing indicator pheophorbide a were elevated. Unlike other manipulated systems, effects of liming and fish manipulation were short-lived and predisturbance conditions were reestablished by 1970.

OSTRACODA IN LAKE QINGHAI, CENTRAL CHINA: A $\delta^{18}\text{O}$ RECORD FOR
CLOSED-BASIN LAKE LEVEL CHANGES SINCE THE LATEST PLEISTOCENE.

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Lake Qinghai, with an area of 4600 km² at 3200 metres above sea level, receives drainage from 35,000 km² on the Tibet-Qinghai Plateau. Seasonally stable atmospheric pressure cells over that area have played a vital role in determining monsoonal patterns. During the last Ice Age, increased albedo reduced the strengths of those cells and aridity prevented the build up of an Alpine-type ice mass. Since that time, Lake Qinghai has remained a closed basin, with lake levels responding to environmental changes.

In 1985 a Swiss-Chinese project completed a seismic survey of the lake floor and recovered a series of basinal sediment cores which reached a ubiquitous seismic reflector at about 5.5 m. sediment depth (ca. 13,500 years B.P.). $\delta^{18}\text{O}$ values from benthic ostracod carbonate preserved throughout those basinal silts record a changing environment for the latest Pleistocene and Holocene.

$\delta^{18}\text{O}$ values of 3 to 5 ‰ for the oldest carbonates are close to those recorded in the modern lake, although levels were then probably near their lowest. Subsequent large short-term $\delta^{18}\text{O}$ excursions, suggesting the rapid response of a smaller body of water, characterised the lake until the onset of the Holocene. A positive $\delta^{18}\text{O}$ excursion of 4.6 ‰ and high rates of authigenic carbonate silt production, mark a dry period coeval with the early Younger Dryas. These $\delta^{18}\text{O}$ excursions are superimposed on a negative $\delta^{18}\text{O}$ trend of some 6 ‰, indicating a net rise in lake level toward the end of the Pleistocene. During several centuries after ca. 10,500 years B.P., a final negative $\delta^{18}\text{O}$ shift of more than 4 ‰ probably records the strengthening of monsoonal circulation. The lake level subsequently fluctuated to perhaps its highest level at about 8000 years B.P. From then until around 3500 years B.P., $\delta^{18}\text{O}$ values became steadily more positive by nearly 7 ‰ due to evaporative enrichment. Deviations from that overall isotopic trend indicate changing lake levels; negative excursions indicating relative high stands and a positive excursions relative low stands. An increasingly negative $\delta^{18}\text{O}$ trend after about 3500 years B.P. probably records generally rising lake levels. $\delta^{18}\text{O}$ values for this century record a sharp positive shift to the modern value of nearly 5 ‰ which is interpreted as being due to a change in the catchment hydrology.

HYDROCARBONS IN LAKE SEDIMENTS

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Limnologists commonly react to the suggestion that there might be commercially significant hydrocarbon pools in lake sediments with frank skepticism. This prevents them from taking environmental impacts from a developing hydrocarbon industry seriously. They are unlikely to undertake baseline studies or offer advice early enough to influence public policy so long as this skepticism prevails. If they conduct deep coring operations without proper assessment of the risk of striking large pockets of gas or pools of petroleum they may meet with serious accident themselves, or cause serious environmental degradation, or both.

Three conditions are needed to produce a commercial petroleum pool in a sedimentary body. There must be a source rock with a high content of organic matter, preferably of planktonic origin. The source rock must be held at a high enough temperature long enough for the organic matter to become mature petroleum, but not so long that the petroleum becomes over-mature. We are considering the formation of oil, not ashes. Finally, the mature petroleum must migrate through the source rock to trapping structures where it will accumulate in pools large enough to be located and drilled. We are considering the formation of oil, not oil shale.

Even though the trapping structures may presently be under the sea, a very substantial part of commercial petroleum is lacustrine rather than marine in origin. Several existing lakes on the continent of Africa, and presumably elsewhere in the world as well, are large enough and old enough, and have a deep enough sedimentary wedge, to be very serious commercial prospects. The sediments are covered with seismically-transparent water rather than the obscuring salt beds that are common in marine oil-fields. It is easier to decipher the sedimentary structure of potentially oil-bearing lake beds than marine ones and so the problem of locating commercial petroleum pools in traps is simpler. Lake sediment is commonly an order of magnitude richer in organic matter than marine sediment, and so is a particularly rich source rock. The petroleum potential of Lake Tanganyika is probably comparable with that of the entire coterminous United States. Serious geological opinion holds that even a much smaller and younger lake, such as Bosumtwi in Ghana, may be a commercial gas prospect.

PALEOLIMNOLOGY OF NEUSIEDLERSEE, AUSTRIA. - 1. THE SUCCESSION
OF OSTRACODS

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Neusiedlersee is a shallow (A: 300 km², z_{max}: 1.8 m) alkaline lake, which came into existence by tectonic subsidence about 12,000 - 13,000 years ago. At present half of it is covered by *Phragmites australis* which developed after the lake fell dry for the last time in 1868.

Due to its astatic character with about 100 - 200 dry periods since the lake came into existence most of the sediment of the open lake on top of a mighty tertiary layer presents a mixture of terrestrial and lacustrine components and because of disturbance by wind is missing any stratification. Preliminary investigations, however, demonstrated that within the *Phragmites* belt - especially landward - such a stratification does still exist.

In order to learn more about the history of the lake 18 deep freeze cores (135 - 190 cm) from the *Phragmites* belt were investigated for chemical data (see Gunatilaka, this volume) and the succession of ostracodes. Most of the cores contain tertiary material (forams, ostracods) at their base followed by a cold water fauna as indicated by *Cytherissa lacustris*. Indication of high alkalinity (males of *Limnocythere inopinata*) and salinity in general (*Heterocypris salina*) was found in only a few cores.

Reference: Löffler, H (ed.) (1979) Neusiedlersee, Limnology of a Shallow Lake in Central Europe. Junk bv Publishers, 543 pp.

THE HISTORY OF DEVELOPMENT OF BYELORUSSIAN ANCIENT LAKES IN
PLEISTOCENE

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The study of sediments of the ancient lakes by paleobotanical methods (including the method of diatom analysis) promotes not only the more detailed of the evolution of the reservoirs themselves, but also to the reconstruction of the history of surrounding landscapes. Thus, lake deposits are a valuable source of paleogeographical information.

The ancient lacustrine deposits are wide-spread on the Byelorussian territory. They were stripped both in natural exposures and in boreholes. The results of studying these sediment permit reliably distinguish three main stages in the development of Byelorussian lakes corresponding to three Interglacial periods.

The most ancient stage is correlated with the Byelovezha Interglacial (Early Pleistocene), its sediments being mainly represented by lake and oxbow-lake formations. These deposits are mainly developed in the middle and south-eastern parts of Byelorussia. According to the diatom composition and the thickness of sediments, the paleoreservoirs had covered considerable areas and were of the middle depth.

The Middle Pleistocene sediments of the Likhvin (Holstein) Interglacial meet to the second stages of development of paleoreservoirs. The deposits of this period occur within the area spread towards glacial valleys and exaration depressions, more seldom over low ancient watersheds. They are represented by lacustrine, bog and alluvial deposits, which were formed under conditions of temperate humid climate.

The Upper-Pleistocene ancient lakes corresponding to the Mikulino sediments is comparatively small - 2-6 m, reaching sometimes 25 m.

The numerous finds of lake sediments of different Pleistocene epochs indicate that Byelorussia was a vast lacustrine country all over the Pleistocene.

HOW LONG WAS THE YOUNGER DRYAS? PRELIMINARY EVIDENCE FROM AMS-DATINGS
AND LAMINATED SEDIMENTS

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Extensive AMS-dating (Accelerator Mass Spectrometry) series (over 90 dates) on Late-Glacial terrestrial plant remains from two Swiss Plateau lake deposits (Lobsigensee, Rotsee) suggest two periods of constant radiocarbon age. The first so called age-plateau occurs at ca 12,600 yrs B.P., coinciding with the onset of *Betula* reforestation as well as with the first shift in the oxygen isotope record ($\delta^{18}O$). The second, more conspicuous plateau lies at 10,000 yrs B.P., i.e. at the very important transition from the Late-Glacial to the Holocene, where pollen values of thermophilous trees (*Corylus*, *Ulmus*, *Quercus*) rise substantially. Both plateaux coincide with periods of climatic warming and with important changes within the pollen assemblages. However, these age-plateaux would seem to make it impossible either to estimate the timing of these changes or to calculate accumulation rates using ^{14}C -dependent dating techniques.

Yet, we are in the fortunate position of having access to a Swiss Plateau lake (Soppensee) with laminated sediments. The laminations begin to occur as early as Alleröd (before the tephra layer of the Laacher See, 11,000 yrs B.P.) and end in the course of the Atlantic (ca 5,000 yrs B.P.). Pollen and diatom analyses as well as sediment thin-sections provide evidence of the seasonality of the carbonate-rich Holocene laminations, whereas sediment thin-sections alone are used to investigate the nature of the carbonate-free Late-Glacial laminations.

Counts of these annual couplets may eventually lead to a more precise estimate of the duration of the Younger Dryas cold phase as well as the timing of the vegetational changes at the transition from the Late-Glacial to the Holocene.

DOMINANT DIATOMS IN THE INTERGLACIAL LAKES OF THE MIDDLE
PLEISTOCENE OF POLAND

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Presented is an analysis of diatoms that are most common in the lacustrine sediments of two profiles /Wola-Grzymalina-59 and Ławki-7/ which represent the Ferdynandów Interglacial /= Voigtstedt, Byelovezha, Cromerian 3+4 in the Netherlands/ near Bełchatów in Central Poland and from three sites /Biała-Podlaska, Krępiec, Adamówka/ representing the Mazovian Interglacial /= Likhvin, Holstein/ in southeastern Poland.

The greatest relative frequency and differentiation of planktic diatoms has been encountered in sediments characterizing the preoptimal and climatic optima of both interglacials. In the Wola-Grzymalina-59 section as well as in the Krępiec site diatomites have been formed several up to some dozen metres thick.

Cyclotella, Stephanodiscus and Aulacoseira dominated in the sediments in the lake of the Ferdynandów Interglacial near Bełchatów. Specimens closest to the fossil species of Cyclotella raczickiae made the greatest share, a form found so far only in the lacustrine sediments of the Byelovezha Interglacial in Byelorussia which is classified there to the Lower Pleistocene.

In sediments representing the Mazovian Interglacial in the Adamówka and Krępiec sections the most characteristic are Cyclotella comta var. lichvinskis /C. radiosa/ and C. vorticosa. At Krępiec numerous are also Stephanodiscus and at Biała-Podlaska Aulacoseira is the most common genus.

Both qualitative and quantitative differences in the diatom spectra from the studied sediments of the interglacial lakes may result from different geographic position and differences in geology around these lakes. Other factors in this respect may have been the size and depth of the lakes in question as well as the chemism of the waters, duration and various climatic conditions ascribed to the Ferdynandów and the Mazovian interglacials.

SEDIMENT PROVENANCE AND SEDIMENT YIELD OF DAYAT IFFIR, MOROCCO

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Sediment provenance and sediment yield of Dayat Iffir, a solution lake in the Middle Atlas region of Morocco, was determined by comparing the magnetic mineralogy, lithology, chemistry and sedimentology of catchment soils with ^{210}Pb and ^{14}C dated lake-sediment cores.

Topsoils in the catchment of Dayat Iffir have large secondary ferrimagnetic, superparamagnetic and viscous components, and a low carbonate content. Subsoils have high carbonate contents, low organic contents and primary, coarse-grained, single stable domain ferrimagnets. Colluvium has the highest carbonate content and primary, single stable domain ferrimagnets derived from the bedrock associated with an antiferromagnetic 'matrix'.

The sedimentary record can be divided into 5 zones the lower 3 zones consist of partially weathered bedrock accompanied by periodic influxes of both topsoil and colluvium. Following a substantial influx of topsoil and woodland soil in zone 4, an increasing proportion of the sediment is derived from subsoil/cultivated soil; however, the majority of sediment in zone 5 is derived from topsoil. Within each zone two types of susceptibility peak can be identified. 'Major' peaks are derived from the influx of topsoil and woodland soil, containing a high proportion of superparamagnetic secondary ferrimagnets. 'Minor' peaks have higher carbonate contents and a higher proportion of fine grained, single stable domain, primary ferrimagnets reflecting the influx of colluvium.

^{210}Pb and ^{14}C dates show that the sediment cores cover the last 1600 years. From ca. 300 to 1500 AD, zones 1 to 3, accumulation rates of 10 t yr⁻¹ reflect low level influx of partially weathered bedrock. Throughout this period, intermittent influx of woodland and topsoils suggests that periodic deforestation occurred. Between 1500 and 1845 substantial influx of topsoil and woodland soil suggests a period of extensive deforestation. From 1845 to 1935, the lower part of zone 4, sediment yields increase from 30 to 70 t km⁻² yr⁻¹, corresponding to a gradual increase in the proportion of subsoil/cultivated soil in the sediment which may reflect an increase in the amount of land brought under cultivation. Between 1935 and 1955 the higher sediment yield of 140 t km⁻² yr⁻¹ is due to an influx of weathered bedrock and 'matrix' from the steeper northern slopes of the catchment. From 1955, the period covered by zone 5, the increase in the sediment yield to 200 t km⁻² yr⁻¹ corresponds to an influx of topsoil and woodland soils, possibly the result of increased grazing.

ATMOSPHERIC PARTICULATE DEPOSITION IN RECENT LAKE SEDIMENTS

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Mineral magnetic records of recent sediments from Buttermere and Crummock Water (the English Lake District) show a marked two-stage increase in the concentration of ferrimagnetic particles along the core profiles. The latest of these increases has been dated to circa 100 years ago, and the increase continues to the present. Mineral magnetic data show that small (single domain) ferrimagnetic particles, characteristic of certain industrial emissions, may be responsible for this increase.

Results of STEM/EDAX examination of high quality extracts are presented, which allow the identification of the distinctively-shaped industrially-derived particles when present.

MINERAL MAGNETIC RECORD OF CHANGING CATCHMENT EROSION IN LAKE SEDIMENTS,
EVIDENCE FROM CRUMMOCK WATER AND BUTTERMERE, THE ENGLISH LAKE DISTRICT.

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Mineral magnetic and chemical properties of lake sediment cores are used to investigate the record of catchment erosion in lacustrine sediment cores from Buttermere and Crummock Water, (the English Lake District). Directional magnetic properties allow the construction of a comparative chronostratigraphy, whilst non-directional (mineral magnetic) properties of the lake sediments are shown to be a sensitive indicator of changing erosion styles within the catchment.

Three distinctive periods of erosion style are identified. These correspond to:

- i) the glaciolacustrine depositional environment
- ii) a period of low allochthonous sediment input during the British climatic optimum
- iii) dramatically increasing rates coinciding with the expansion of human settlement in the catchment area.

MEROMIXIS AND EARLY MAN AT LÄNGSEE, A REAPPRAISAL

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A 2.2 m portion of the Längsee - core retrieved for the 4th Int. Symp. on Paleolimnology was freeze-dried, soaked with epoxiresin and thin sectioned for study of the microfazies.

Apart from the discovery of the "Laacher See" pumice layer of Allerød age, the sediment column shows beautifully layered annual laminations over long periods of the Holocene (FREY 1955, 1956). These laminated sequences macroscopically and microscopically resemble to the last details the muds of lakes of similar size in the alpine foreland (Faulensee, Schleinsee etc.). From their lithological aspects and from their chemistry, these sediments are not true sapropels. It is assumed that they have been deposited in lakes whose hypo-/monimolimnion was seasonally devoid of oxygen. These conditions lasted sufficiently long to prevent the invasion of burrowing organisms able to destroy sediment texture.

A sequence of cyclic lamination began in the neolithic period. At an approx. 6 years cycle, massive graded bedded silt layers with considerable quantities of charcoal splinters were laid down after the summer sublamina, indicating the impact of early man. In the early stage, the lake recovers from these impacts, and produces calcareous sublamina during summer and organic during the rest of the year. After twenty years, however, the silt layers show bioturbation due to longer presence of oxygen at the lake bottom. Some 35 years later, following a last silty layer, the lamination disappears totally. A slightly coarser completely mixed sediment is deposited. The time interval with complete mixing is not known exactly, however, is estimated to last for several decades or centuries.

Finally meromixis comes into being, again indicated by lamination. Under sapropelitic conditions, individual laminae attain double thicknesses of the layers mentioned above. This is partly due to increased precipitation/preservation of the summer-chalk. Traces of bioturbation cannot be detected. Disturbances of the sediment texture are assigned to methane ebullition.

LATE-GLACIAL PEDIASTRUM SPECIES FROM LYSMOSEN, DENMARK.

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Most palynological works concerning the development of the vegetation in the Late-Glacial period contain quantitative information on the green algal genus *Pediastrum*. Due to the content of sporopollenin in the cell walls, the coenobia of *Pediastrum* are very well preserved in the sediments and the percentage distribution of the genus has been used as an indicator of changes in hydrology and in trophic conditions of the water body.

The purpose of the present investigation, made in cooperation between a palynologist and a phycologist, was to show whether a determination on the species level could reveal any trends in the succession of species and whether these trends could be correlated with changes in the environment.

The percentage distribution of *Pediastrum* species is presented together with a pollen diagram, and possible correlations are discussed. Lysmosen, a former bog, is situated in the south-eastern part of Jutland. The sedimentation started in Older Dryas and continued through Allerød and Younger Dryas until the gyttja-sedimentation stopped by a drainage and overgrowing of *Sphagnum* in the very beginning of the pre-Boreal period. Early Allerød is dated to 11.630 ± 120 B.P. by C_{14} on a bone from a Giant Deer (*Megaloceros giganteus*), found in the bog in 1985.

INISHBOFIN, CO. GALWAY - RECONSTRUCTION OF THE HOLOCENE
ENVIRONMENTAL HISTORY OF AN ISLAND OFF THE WEST COAST OF
IRELAND.

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Studies on the palaeoenvironmental history of islands off the Irish coast are few, and those available are based on investigations of peat deposits. Inishbofin, which lies about 7 km off the Galway/Mayo coast, was selected as a potentially interesting island for a case study because of its considerable geological and edaphic diversity, the presence of rarities such as Eriocaulon aquaticum, the most important North American element in the present day Irish flora, and the island's long history of human settlement which probably extends from early Neolithic times down to the present day. The study of its history of post-glacial colonization is of particular interest in view of its extreme western location, surrounded by the deep waters of the Atlantic.

Preliminary results of pollen analytical studies of an 8 m core from Church Lough, a small lake situated beside the monastic settlement of St. Colman (founded A.D. 664), will be presented. Woodland history is reconstructed and evidence for human impact and farming activity in the catchment is discussed. The results are compared with those from several comparable investigations on the nearby Connemara mainland, which are now being completed.

WHAT THE METAL AND METALLOID STRATIGRAPHY IN LAKE SEDIMENT
CORES REVEALS ABOUT ACIDIC PRECIPITATION

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Sediment cores, dated by ^{210}Pb and/or varves, from lakes receiving neither point source nor non-point source discharge of metals and metalloids from within their watersheds, have been used to: (1) Develop a chronology of atmospheric deposition of trace elements, (2) Define fluxes and identify sources of those elements, (3) Establish if acidification of the water column has occurred, (4) Establish that fluxes of some metals (especially Al and Fe) from the watershed to the lake have increased in recently acidified systems, (5) Determine the net maximum alkalinity generation represented by sulfate reduction and storage, (6) Determine the maximum net alkalinity associated with metal release from the sediment, (7) Determine temporal variations in the speciation of metals retained in the sediment resulting from altered chemical conditions in the watershed soils and streams, and (8) Determine the extent of sediment focussing of certain metals (e.g. Pb) relative to the atmospheric flux.

Differences in techniques of coring, radiometric or varve dating, chemical analysis, and data manipulation exist among laboratories and researchers. Nonetheless, the chronology and magnitude of inferred air pollution and atmospheric deposition of trace metals is surprisingly consistent. On a continental scale, biogeochemical fluxes of Pb and Hg are now dominated by atmospheric deposition. On a scale of 100s to ca. 1000 km from sources, atmospheric deposition dominates or contributes significantly to the fluxes of Be, Cd, Cu, V, and Zn. Unique point source emitters dominate local fluxes of elements such as As, Ni, and Se. In eastern North America and parts of Europe, the atmospheric deposition of Al, Ca, Fe, Mn, and Ti is a significant fraction of inorganic sediment accumulation rates in lakes with low accumulation rates.

ACCURACY AND PRECISION IN SEDIMENT CHRONOLOGY

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Several complications are met at radiocarbon dating of limnological samples. The contamination problem is rather obvious. Since lake sediments usually is composed of allochthonous and autochthonous material the origin must be considered. The organic content may give some guidance. Graphite in the catchment area and a low organic content should be a warning for a potential risk for severe errors in the dates. Organic material from the surroundings may be displaced into a lake by creeks, snowslides and by wind. Such material may be older than or contemporaneous with the sediment deposited at the same time. Water-level changes and wave action may cause erosion and thus admixture of old material. Such contamination can sometimes be traced by different fractions extracted mechanically or chemically. The accelerator technique has made it possible to date small samples and thus macrofossils can be selected as the material to be used for dating much more frequently than is possible with the conventional technique for activity measurement.

Another problem is the reservoir effect - thus the lower ^{14}C activity of the dissolved bicarbonate and carbon dioxide than of the atmosphere. There may be several reasons besides dissolved carbonates in hard-water lakes. Some plants even use carbon dioxide in the sediment. It is thus to be expected that submerged plants will be dated too old. Selection of plant remains for dating is thus no guarantee for a good date. The material to be preferred would be terrestrial material as tree leaves or remains of emergent plants.

Bioturbation must not be forgotten since this means that old material may be found too high in a sediment and that young material can be brought downwards in the sediment. A single date may be very misleading. Under rather stable conditions a fair idea about the sediment accumulation rate can be estimated and acceptable dates be received in spite of the mentioned complications.

It may be prosperously sieving gyttja samples to remove roots and rootlets. Roots in peat should also be removed. Diagrams are available for the errors due to certain degrees of contamination by younger or older material.

The ^{13}C content must be measured to allow a normalisation. The present knowledge of the secular variations of the ^{14}C activity allows calibration of dates made on wood etc. The same curves can not be used for submerged material because of the lower ^{14}C activity. Sudden changes of the atmospheric ^{14}C activity are smoothed. Certain age ranges give better resolution than others. Recent curves indicate that strange results are to be expected for Holocene samples with a real age of 7000 years or older. Finally bacterial influence during storage may influence the isotopic composition.

LATE HOLOCENE RECORD FROM A TROPICAL LOWLAND BASIN: WAIGANI LAKE, PAPUA NEW GUINEA

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Sediment cores (up to a depth of 4.8 m) from Waigani Lake (9°22'S, 147°10'E) in lowland Papua New Guinea consist of four distinct layers: 'Layer I' (0 to 0.55 m depth) consists of pale brown to greenish organic sludge with a thin but distinct basal zone of plant fragments. This overlies the dark brown crumb-like material of 'Layer II' (0.55 to 0.75 m). A pale-coloured clay, 'Layer III' continues to 3.8 m depth and overlies dark peaty material ('Layer IV'). Carbon-14 dates show that the bulk of 'Layer III' was deposited between about 950 ± 90 BP and 2540 ± 80 BP. This equates to an average rate of sediment accumulation of approximately 1500 mm per 1000 years and indicates a very high erosion rate if all the material were derived from the local catchment. The Waigani Basin drains into the nearby Laloki River - a major river draining the Owen Stanley Range. Clay mineralogy and elemental analyses (XRF) showed that it was possible to differentiate between the two likely sources: Waigani and Laloki catchments. The results showed that the bulk of the sediment prior to 950 BP was derived from the Laloki River. Diatom counts from core sections also indicate rapid deposition during this period. To date the source and depth of 'Layer IV' has not been determined but dating shows that peat accumulation occurred between 2540 and 3580 ± 80 BP. This site may prove useful for assessing changes in the local and regional environment since the last glacial and it is planned to add pollen analysis and mineral sediment magnetics to refine the interpretation.

THE USE OF LAKE SEDIMENTS TO INFER RATES OF CATCHMENT EROSION : A CASE
STUDY FROM SLAPTON , SOUTH DEVON.

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Current sediment yield estimates from lake sediment based studies at Slapton are around $54t\ km^{-2}yr^{-1}$. Rapid sedimentation in one feeder valley has amassed some 34,000 tonnes of sediment in a timespan not exceeding 100 years. The probable cause is lake level changes in the last 100 years causing the ponding of water and sedimentation behind a bridge. The implications are that lake sediment based estimates of sediment yield and inferred rates of catchment erosion may greatly underestimate the true value.

REGRESSION OF D'IBERVILLE SEA AND PALEOLIMNOLOGY OF TWO LAKES
FROM SOUTHERN CENTRAL UNGAVA BAY (CANADA)

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The Southern Ungava Bay area (Northern Quebec, Canada) only became deglaciated after 7000 BP (Lauriol & Gray 1987). Penetration of the postglacial D'Iberville Sea far inland accompanied the retreat of the late Wisconsinan ice sheet. Very little is known about its chronology or the sea-level changes which resulted from subsequent glacio-isostatic uplift. Diatom analysis and radiocarbon dating provide new paleoecological data by tracing the isolation of two coastal lake basins from marine waters. The two investigated lakes are situated near Kuujjuaq (Fort-Chimo; 58° 06' N, 68° 24' W).

Paleoenvironmental changes are well documented in the diatom stratigraphies, revealing a continuous record through periods of marine submergence, isolation from the sea, and subsequent freshwater conditions. Diatom succession clearly documents changes in paleosalinity and isolation dynamics.

An initial assemblage of euryhaline marine littoral diatoms is succeeded by a predominance of benthic alkaliphilous *Fragilaria* spp., a feature commonly occurring with isolation from the sea (e.g. Stabell 1985). Throughout the following lacustrine sequences, shifts in diatom population structure have been related to climatic and vegetational changes inferred from pollen analysis. Apart from new autecological information, this interdisciplinary approach allows some general conclusions to be made on the utility of diatoms in providing paleoclimate proxy data. This supports the hypothesis that diatoms are relatively specific indicators of habitat availability, which is related to past climatic changes (Smol 1988).

Although agreeing in general trends, this comparative study of ontogenic patterns of two nearby lakes reveals remarkable differences in diatom succession. The latter emphasizes the strong control that certain allogenic variables, such as lake morphometry and local topography, have on the size and composition of diatom assemblages.

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ANNUALLY LAMINATED SEDIMENTS OF LAKE GOŚCIEŹ, CENTRAL POLAND

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The aim of this presentation is to introduce a site - Lake Goścież - offering special prospects for reconstructing the rates of environmental changes, and planned to be the subject of long-term multidisciplinary studies; its sediments show the annual lamination since ca. 12300 years ago till recent times.

In the lower part of sediment (17-8 m) where the lamination is very regular, the sequence of 9682±50 varves (including 3 small gaps) was found. In the upper (8-0 m) part there are temporary disturbances in varve formation, increasing upwards in frequencies and extent. Here the number of varves is roughly estimated, with the help of X-ray radiographs, to 2670±250. The above chronology may, hopefully, be still improved by examining more profiles, particularly the frozen cores.

The international working group organized for studying the Lake Goścież sediments aims to cover as wide scope of palaeolimnological and other palaeoecological subjects as possible. Up till now the efforts were concentrated mainly on the late glacial part of the sequence.

The measurements of laminae thickness were done for the light and dark parts of couplets separately. The statistical analysis of thickness variations revealed some evidence of periodical patterns. The record of solar 11/22 yr cycle was found in some sections of the profile. The most evident is 200 yr periodicity, which may be correlated with the 14C variations. The continuous mineralogical analysis performed on tape-peel preparations revealed in the lower 17-12 m part of profile four main periods in sediment formation corresponding with the Allerød-Younger Dryas-Preboreal sequence recognized by pollen and Cladocera analysis. The results of stable isotope analysis (18-O, 13-C) give suggestions about the changes in lake temperature and productivity. They will be correlated in detail with the results of other palaeoecological analyses.

THE SEDIMENT COLUMN AS A RECORD OF TROPHIC STATUS: EXAMPLES FROM
BOSHERSTON LAKES, SW WALES.

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Bosherston Lakes are a series of interconnected mesotrophic to hypereutrophic marl lakes. Progressive eutrophication has resulted mainly from the input of phosphorus rich effluent from a sewage treatment works. Cores were taken from four sites of varying eutrophic status and the solid phase analysed for organic carbon, nitrogen and phosphorus, inorganic phosphorus fractions, acid-soluble iron, carbonate and lead-210. Diatom remains were examined in a single core.

In the surface sediment layer, organic C, N and P concentrations and deposition rates generally correlated directly with trophic status and reflected the distance away from the source of high P loading. Palaeolimnological interpretation of the cores is complicated by the effects of natural diagenetic processes. A core from one site, however, shows a clear transition zone at 20-15 cm depth marked by a sharp upward increase in porosity, organic C, N and P, and "iron-associated" P, decreases in organic matter C/N, C/P and N/P ratios, a sharp decrease in carbonate and a change in diatom assemblage. This transition reflects an increase in trophic status at this site probably resulting from an influx of nutrient rich water which occurred when the management of the estate surrounding the lake system fell into decline. Phosphorus fractionation results strongly suggest that the phosphorus binding capacity of the sediments at this site has now reached saturation. This has important consequences for the cycling of P within sediments and particularly for the internal loading of phosphate to the lake system.

DIATOM ASSEMBLAGES IN THE BOTTOM SEDIMENTS OF LAKE ČERNÉ JEZERO
IN SW BOHEMIA, CZECHOSLOVAKIA

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Contemporary and subfossil diatoms in the bottom sediments of Lake Černé jezero in the Bohemian Forest were examined in relation to the water quality and to the lake history during the last few centuries. For paleolimnological reconstruction of the lake, several sediment cores obtained from the interval about 1.20 m below the sediment surface were analysed geochemically, for pollen and diatoms. A reliable chronology of sediment accumulation at some cores, dated by lead isotopes, is under way.

Lake Černé jezero is a small glacial lake located at 1008 m altitude in an extremely acidic environment with coniferous forests /mainly spruce monocultures/ and scattered peat-bogs in the catchment area. It was hollowed out on a gneiss bedrock by a small slope glacier of the Jezerní hora Mt. during the last glacial period /wurm/. The lake is oligotrophic with a low buffering capacity and very low productivity of microplankton. Besides diatoms, cysts of Chrysophytes, synuracean scales, chlorococcal algae, sponge spicules, cladoceran remains and other planktonic elements are also preserved in the lake sediments. The diatoms were used as a parameter for elucidation of the paleoecological conditions of the lake, particularly of its pH values.

The diatom flora, represented chiefly by the genera Eunotia, Anomoeoneis, Pinnularia, Frustulia and Aulacoseira /A. distans s.l./ is acidophilous /pH 5.5 - 6.8/. In the course of deposition of the studied sediments the lake changed only little its oligotrophic character. Nevertheless several variations were recorded in the down core sediments which manifested themselves in the change of pH, in the sediment chemistry and in the content of biota. The most impressive change in the lake trophic status was noted in the diatom assemblages of the uppermost sediment layers of the lake which correspond to the period of the past 30-50 years. It reflects the increase of lake acidification, demonstrated by the decrease in pH values down to 4.5. This resulted in structural changes of the diatom assemblages, particularly in a smaller diatom diversity and in an increase of acidophilous and acidobiontic species frequency. Possible reasons for these phenomena are briefly discussed.

PALEOLIMNOLOGICAL IMPLICATIONS OF HOLOCENE SEDIMENTATION IN THE PLAYA LAKES
OF BRITISH COLUMBIA, CANADA

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The Cariboo Plateau in the southern Interior of British Columbia contains several hundred ephemeral and perennial saline lakes, with $\text{Na-CO}_3\text{-Cl}$, Mg-Na-SO_4 and Na-Mg-SO_4 brines. They are the northernmost group of intermontane saline lakes in the Western Cordillera. Unlike most saline lakes in the western United States, the Cariboo lakes are small, lie within glacial and glacio-fluvial deposits, and did not have large Pleistocene precursors.

The environment of the Cariboo differs in many respects from that commonly associated with playa lake sedimentation. Most of the lakes occur within dense coniferous forest. The region has hot summers (35°C), very cold winters (-45°C) and <90 days each year are frost-free. Most salts (natron, mirabilite) are precipitated in autumn and winter by brine cooling and freeze-out. Three subenvironments dominate the playa lakes: hillslope (eskers or linear glacial mounds), saline mudflat and ephemeral lake.

Short cores (1.0-1.5 m) recovered from many playas have revealed three main lithofacies: pure, massive carbonate muds (magnesite, hydromagnesite, protodolomite); poorly bedded, mixed carbonate-siliciclastic muds; poorly bedded siliciclastic sands and muds. Organic-rich muds (>15 wt.% T.O.C.) and permanent salts are found centrally in some playas.

Most recent sedimentation in the playa lakes has been autochthonous and is a consequence of (i) low relief catchments and groundwater recharge, (ii) the $\text{Ca+Mg/HCO}_3\text{+CO}_3$ ratio in inflow waters being close to unity, thus providing abundant carbonate sediment, and (iii) the dense vegetative cover which has stabilized the soils and limited clastic influx.

The sediment record preserved in many cores is poorly preserved and difficult to interpret because of sediment mixing and disruption by (i) extensive interstitial precipitation of carbonates, gypsum and soluble salts, (ii) wetting-drying cycles, (iii) volume changes associated with dehydration and rehydration of minerals sensitive to the large temperature changes, and (iv) the effects of freezing. Although tephra derived from Cascade eruptions are preserved in perennial lakes, bogs and spring deposits within the region, homogenization of the sediment has destroyed ash beds in some playas. Similar effects are likely in older analogous sequences from seasonally cold environments.

PALAEOBACTERIOLOGY -- WHY NOT?

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In addition to natural sediment-living bacteria, which are not considered here, lake sediments contain allochthonous bacteria that provide information about past conditions in lakes and their catchments. There are three possible types of study material; i) non-spore forming bacteria that might survive long enough to make surface sediments useful for studies of recent conditions, ii) viable spores that can survive for thousands of years in sediments, and iii) subfossil remains of bacteria. This paper presents a literature review giving examples of previous studies using palaeo-bacteria as ecological indicators, discusses methods, and attempts to indicate possible future developments.

PALEODIATOM POTENTIAL OF LAKE BASINS IN EASTERN AUSTRALIA

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Australia's reputation as the driest continent leaves one unprepared for the number and variety of lakes that exist in the eastern half of the continent. They range from shallow, intermittent lunette lakes and pans (some of great size) to permanent volcanic and glacial lakes having depths up to 70 m. While some of the lakes are very dilute, many have relatively high salinities; chloride waters are much more common than carbonate waters.

Geomorphological, paleochemical and biostratigraphic studies of Australian lake sediments are well advanced and have yielded many insights into the past, but paleodiatom studies are in their infancy. What are the prospects? Examination of surface sediments from many lakes and of core material from a smaller number indicates that most shallow basins of the interior possess poor and intractable paleodiatom records, but that at least some of the deeper volcanic lakes of Western Victoria hold good promise. Along the wetter eastern fringe of the continent, prospects are equally mixed. Glacial lakes of Tasmania and the Snowy Mountains may yield valuable diatom records; and the rain forest maars of northern Queensland, some of which have seasonally laminated sediments, are of great interest although diatom preservation is not uniformly good. The dilute lakes of sand depressions on Fraser Island apparently contain very few living or fossilized diatoms but ionically richer coastal lakes are good prospects, judging from the core record of (Australia's) Lake Windermere. An interesting contemporary diatom flora characterizes a small district of sodium bicarbonate lakes east of the Snowy Mountains, but these lakes probably are too intermittent to yield satisfactory stratigraphies.

FOSSIL-FUEL DERIVED PARTICLES IN LAKE SEDIMENTS.

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Carbonaceous particles and mineral ash spheres derived from high temperature fossil-fuel combustion are found in considerable numbers in the upper levels of sediment cores taken from areas of high acid deposition. Sites in the United Kingdom show close correlation between the onset of atmospheric contamination as indicated by carbonaceous particles, and the acidification of lakes as indicated by diatom analysis.

Carbonaceous particles are resistant to chemical attack and so extraction methods have been developed to remove unwanted fractions of the sediment by selective digestion. The particles are then more readily available for chemical characterisation using EDS techniques. An extraction method for mineral ash spheres has also been developed so that the concentrations of both particle types can be compared.

The methods have been applied to lake sediments over the U.K. and abroad to study the spatial and temporal distribution of the particles.

A CATALOGUE OF MORPHOTYPES OF CHRYSOPHYCEAN CYSTS IN LACUSTRINE SEDIMENTS
FROM INSULAR NEWFOUNDLAND, CANADA

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In the absence of historical, long-term, surface water pH data, algal microfossils are becoming increasingly used to document patterns of lake acidification from stratigraphic studies of fossilized flora in recently deposited sediments. In lacustrine sediments from insular Newfoundland, chrysophycean cysts are more abundant than diatom frustules and consequently can provide very precise paleoecological information on the history of lake water quality. The Canadian Department of Fisheries and Oceans has undertaken a study, using assemblages of chrysophycean cysts as a palaeoindicator, to interpret the pH history of acidic lakes. The main objectives of this study were to: 1) survey the chrysophycean cyst flora of a large number of Newfoundland lakes of varying pH to document existing morphotypes and their general distributions, 2) identify the important environmental factors controlling the distribution of chrysophycean cysts, and 3) develop indices and predictive equations to infer historical lake water pH from cyst assemblages.

This paper presents the first results from this research study. Detailed SEM (scanning electron microscope) photographs and morphological descriptions of cysts from lakes with pH ranging from 4.86 to 8.30 were used to establish a catalogue of commonly encountered morphotypes. This documentation will then be applied in evaluating environmental influences on morphotype distributions and in developing region-specific predictive equations to infer lake pH histories.

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LATE QUATERNARY LAKES IN TULE VALLEY, WESTERN UTAH, USA

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Geomorphic, stratigraphic, and geochronometric evidence indicate that during marine oxygen-isotope stage 2, Tule Valley, Utah, contained an independent closed-basin lake before and after a period of integration with Lake Bonneville. Pleistocene Lake Tule became the Tule Valley embayment of Lake Bonneville approximately 19,500 yr B.P. when the transgressing Lake Bonneville spilled over the lowest point on the drainage divide between the two basins. When Lake Bonneville stood at the brink of overflow Lake Tule also occupied the highest level it had yet attained in the lake cycle. At this shoreline elevation of approximately 4645 ft (1416 m), Lake Tule had a maximum depth of about 250 ft (76 m). A continuous band of no shorelines in Tule Valley between the 4645-ft (1416-m) level and a shoreline at 4740 ft (1445 m) indicates that Bonneville basin overflow rapidly raised the Tule Valley water level to the equilibration elevation. Tule Valley remained integrated with Lake Bonneville through Bonneville and Provo Shoreline time. Integration ceased shortly after 14,000 yr B.P. when climatic factors caused Lake Bonneville to fall below the 4740-ft (1445-m) threshold elevation. The re-isolated Lake Tule apparently dessicated completely within only a few thousand years. A radiocarbon date (Beta-29185) on fresh-water gastropod shells collected from a Lake Tule shoreline at 4426 ft (1349 m) supports the inference that the lake retransgressed at least 30 ft (9 m) sometime before 9140 yr B.P. This very late Pleistocene or early Holocene high lake level is probably equivalent to the Gilbert and Gunnison Shorelines of the Great Salt Lake and Sevier Desert portions of the Bonneville basin, respectively.

THE EUTROPHICATION HISTORY OF LAKE SÄRKINEN AND THE EFFECTS OF LAKE AERATION

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Lake Särkinen is a small lake in the parish of Sotkamo. In the immediate vicinity of the lake are situated the Vuokatti Institute of Athletics and a holiday centre of the State Railways. The sewage load corresponded with around 45 inhabitants in the years 1956 - 59 and around 70 inhabitants in the years 1959 - 69. Thus the lake was very eutrophic after the middle of the 1960's. The nutrient load was strongly reduced in 1969 and aeration was started in 1980.

The dating of the sediments was made with ^{210}Pb -analysis from two profiles, which gave uniform picture of the changes in sedimentation. There is a distinct dichotomous sedimentation maximum at the turn of the century. It seems that a little pond has been emptied to lake Särkinen. After a sedimentation minimum in about 1920's - 1960's, the sedimentation rates rise to the present level.

The diatom analysis shows the phases of the eutrophication. A very clear change happens already at the beginning of 20th century and another at the turn of 1950 - 60's. The surface subsample, which represents the 1980's, shows a normalization in Diatom flora and the beginning of recovering. The other microfossils, Cyanophyta and Cladocera, indicate that the blooms of bluegreen algae started probably in the 1920's.

The nutrients of the sediment and analyzing the solubility of phosphorus show the signs of oxygen depletion. The sediment phosphorus seems even now to be readily soluble. Ending the aeration includes a risk.

PALEOLIMNOLOGY OF LAKE MENDOTA, WISCONSIN, USA

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Analysis of a sediment core from Lake Mendota, documents changes in the composition of pelagic cladocera over the last 200 years that can be correlated with historical events impinging on the lake. The 1.16 m frozen crust core provides a complete section through the iron sulfide-rich black gyttja deposited since Euro-American settlement of the area ca. 1820-1840 and penetrates into buff marl sediments characteristic of much of the lake's 12-16,000 year depositional history.

The lowermost section of the core, Zone A, buff marl (pre-1820 A.D.) is characterized by low zooplankton deposition rates ($< 100 \text{ cm}^{-2}\text{yr}^{-1}$) and a pelagic zooplankton population composed of 50-80% Daphnia galeata mendotae. Bosmina longirostris is the secondary species and D. pulex is a minor component. The fairly abrupt change from marl to gyttja deposition (ca. 1820) in Lake Mendota is accompanied by an increased zooplankton deposition rate ($> 900 \text{ cm}^{-2}\text{yr}^{-1}$) and a pelagic zooplankton population dominated by D. galeata ($> 80\%$). Concomitant with this change are parallel increases in Chydorus sphaericus remains and Filinia longisetata resting eggs, indicators of eutrophication. This period (Zone B, 1820-1900 A.D.) coincides with the rapid development of agriculture in the Madison area and thus a time of major input of nutrient-rich runoff. During this time the lake was dominated by large populations of cisco (Coregonus artedii) and stunted yellow perch (Perca flavescens). The zooplankton deposition rate of Zone C (1900-1970 A.D.) is lower than that of Zone B (ca. $700 \text{ cm}^{-2}\text{yr}^{-1}$). More importantly, D. galeata falls to less than 45% of pelagic zooplankton, while the formerly insignificant D. pulex increases to 50-60%. This period corresponds with a decline to near extinction of cisco, a size-selective predator on zooplankton. Release of predation pressure on the large D. pulex likely accounts for the increase recorded in Mendota sediments. Zone D (1970-1984 A.D.) sediments record a further decline in zooplankton deposition rate (ca. $400 \text{ cm}^{-2}\text{yr}^{-1}$) which may correlate with a reduction of nutrient in 1971. A switch back to D. galeata (ca. 50%) exceeding D. pulex (ca. 20%) in the sedimentary record may reflect a return to size-selective predation on large Daphnia by cisco, which reappeared suddenly with a strong year class in 1977.

STRATIGRAPHY OF THE SUBFOSSIL CHIRONOMIDAE (DIPTERA) FROM LAKE GRASMERE,
SOUTH ISLAND, NEW ZEALAND, DURING THE LAST 6000 YEARS.

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The subfossil chironomid fauna of a 3.26 m long sediment core from Lake Grasmere has been analysed. The sediment record covered the last 6000 years of the lake's developmental history. A preliminary pollen analysis (McGlone, pers. comm.) showed that by 6000 years BP Nothofagus forest was already established in the catchment area of the lake. An increase of grass pollen at the 30 cm level of the core indicated the arrival of Polynesians, whereas the presence of European settlers was shown by Pinus and Rumex pollen in the sediments of the core from 6 cm upwards.

The subfossil chironomid taxa of Lake Grasmere belonged to the subfamilies Tanytarsini, Orthocladiinae, Chironomini, Tanypodinae, and Heptagyni. Tanytarsini were the dominant component of the fauna with Corynocera sp. as the most abundant species during the pre-Polynesian time (before 1000 years BP).

The abundance and composition of the subfossil chironomids fluctuated markedly over the last 6000 years. These fluctuations could be partly correlated to changes in the stratigraphy of the sediments in the core. Layers of highly minerogenic sediment contained the lowest numbers of remains whereas maxima of abundance were found in the sections of the core with the highest proportion of organic matter.

It is suggested that major shifts in the structure of the chironomid community have been mainly caused by changes in the hydrology and inflows of the lake and the rate and type of sedimentation, and only to a lesser extent by changes in lake productivity.

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Holocene environments in the central Sahara

Based on recent corings in palaeolakes in N-Mali (Taoudenni) and N-Niger (Segedine, Fachi) it was possible to detect a northward shift of the desert-savanna border of about 500 km to 20-22°N during the middle holocene.

During the early holocene the saharan savannas were established in these regions and in the late holocene the saharan desert vegetation took place and degraded with several oscillations to its present situation.

During the middle holocene the monsoonal summer rain regime was predominating but there were strong interactions with the atlantic cyclones too. This interaction diminished in the late holocene.

The question whether the salt formations of these palaeolakes were influenced only by evaporation of the water body or by a remobilisation of salts due to neotectonic activities along some faults and dykes will influence the reconstruction of palaeoclimatic conditions. The ability of lake sediments as information traps or sources in these regions will be discussed

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Rev. Geogr. phys. et Geol. dynamique, XVII, 175-198

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CNRS Marseille

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THE PALEOECOLOGICAL INTERPRETATION OF TWO MIOCENE LAKE DEPOSITS

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The freshwater lake sediments deposited in two explosion craters of upper Miocene age were studied. The ecologic changes in the two lakes were determined. The two lake deposits were dated by use of mammal fossils, the Andance Mountain is considered as lower Turolian (8.5 - 8.0 m.a.), mammal zone MN 11 while the younger layer of Rochessaue structure corresponds to middle Turolian, MN 12. The presence of mesothermal, oligothermal - mesothermal and oligothermal species of diatoms in the paleolake Andance indicated a cool temperate environment while the loss of the mesothermal species in the younger paleolake at Rochessaue is interpreted as showing a cooling trend in the climate. The higher percentage of aerophilous diatoms found in the younger paleolake at Rochessaue seems to indicate a dryer climate.

PALEOLIMNOLOGY IN ENVIRONMENTAL MONITORING, OR ARE THERE
PRISTINE LAKES IN FINLAND?

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The watershed of Lake Iso-Hietajärvi in East Finland was chosen to one of four Finnish Intergrated Monitoring areas belonging to an international environment monitoring programme. A paleolimnological study was carried out to ascertain: 1) whether the area is pristine enough to qualify as a monitoring area and 2) the quantity of changes that have occurred in the system due to long-range environmental pollution so far.

^{210}Pb -dating (CRS) revealed a period of increased sedimentation from the 1920's to 1950's. Sedimentary pigments indicate contemporaneously increased productivity and deteriorated oxygen conditions. A possible explanation is that the lake's outlet and its water level may have been to facilitate timber floating in the downstream creek system, even though the catchment forest was never felled.

Assemblages of diatoms and Cladocera were also altered somewhat during this period, but water quality seems not to have changed much: e.g. the diatom-inferred pH has remained in the range 6.5-6.7 (same as measured values 1987-88) throughout the studied period.

^{210}Pb dating allows transformation of analyzed heavy metal concentrations into yearly fluxes, and thus estimation of the history and present rates of atmospheric fallout in the lake.

IMPROVING PALEORECONSTRUCTING EFFORTS UTILIZING SCALED
CHRYSOPHYTES: TRANSFORMING SCALE COUNTS TO CELL NUMBERS

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By virtue of their siliceous cell coats, the group of organisms referred to as the scaled chrysophytes can be used to reconstruct historical conditions of lakes. Scaled chrysophytes are often an important component of the phytoplankton community, are strictly euplanktonic and are often very sensitive to shifts in lakewater pH, temperature and nutrient regimes. Many species have restricted distributions along environmental gradients making them especially attractive in reconstructing efforts. Unlike diatoms, the siliceous armours of scaled chrysophytes are composed of a number of scales and bristles imbricated in a very precise manner. When a cell dies the siliceous coat becomes disarticulated and the individual scales become deposited in the sediments. The quantification of cell densities from scale counts is not yet possible because the numbers of scales per cell are not known. Consequently, using current paleolimnological methods, the importance of species with greater numbers of scales are overemphasized. The focus of this research was to determine the number of scales per cell per species which could be used to transform data sets of scale counts into cell densities.

Essentially, the basic patterns of overlap of scales on the cell were used to make the estimates of the number of scales per cell per taxon. Scale and cell dimensions and the degree of overlap between adjacent scales were determined using image analysis of SEM micrographs. The percent to which a scale is exposed on an intact cell ranged from 40 to 70 %, but was constant for a given species. Rotational geometry was used to determine the mean surface areas of cells for individual species. Using the mean surface areas of a scale and cell and the % exposed factor, the number of scales per cell per species were determined. A regression model was developed for use on species that preserve poorly or are rarely encountered. The implications of this research in paleolimnological research will be discussed.

ARE WE BUILDING ENOUGH BRIDGES BETWEEN PALEOLIMNOLOGY AND AQUATIC
ECOLOGY?

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Few paleolimnologists would argue that our science has made substantial advances over the last decade. A simple perusal of the development in procedures and applications, conveniently documented at four- or five-year intervals in previous symposium volumes, should convince any skeptic. The papers presented at this symposium further demonstrate that paleolimnology continues to gain momentum.

One of the biggest advances in paleolimnology has been the large increase in the quantity and quality of information we have on biological indicators. Researchers have shown that each additional group of indicators adds information, and does not simply confirm information gleaned from other groups. The whole is greater than the individual parts. Striking advances have also been made in the ecological interpretation of assemblages, and in many ways the strides paleolimnologists have made in quantifying and interpreting the environmental optima and tolerances of species have surpassed those made by "neo-aquatic" ecologists. On the other hand, paleolimnologists have been slow or perhaps reluctant to use our new and powerful approaches to test a wealth of hypotheses being generated by rapidly expanding ecological theory. The many advantages of having a temporal record providing information on 1000's of years of community interactions has much to offer aquatic ecology. Our techniques have advanced to the point where we can accept these challenges and begin evaluating hypotheses that otherwise remain untested. In many cases, we have been negligent in making neo-ecologists aware of the value and sophistication of our approaches, and therefore a further challenge is to communicate the relevance of our findings to ecological theory. The far-sighted contributions of the late Prof. E. Deevey, Jr. should serve as an inspiration to those working in new research areas and show us how we can integrate our studies with those undertaken by other ecologists.

THE PIRLA II PROJECT: PALEOECOLOGICAL INVESTIGATION OF RECENT LAKE
ACIDIFICATION II

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The original PIRLA project was a broadly interdisciplinary paleolimnological investigation of five to fifteen comparable watershed/lake systems from each of four low-alkalinity regions in North America that are currently receiving acid deposition. The study was successful in increasing our understanding of the timing, rates, and magnitude of acidification (and other chemical changes), and the regional and inter-regional patterns of lake acidification. Another major legacy of the PIRLA project was the refinement and documentation of many research protocols vital to coordinated paleolimnological activities.

Although PIRLA and other projects in North America and Europe demonstrated acidification of some lakes, there are no reliable quantitative estimates of the extent to which pH has decreased in the nearly 3000 lakes in the Adirondack Mountains, NY. With the PIRLA II project, we are making regional estimates of lake acidification through analyses of lake sediment cores from 37 randomly selected lakes. Diatom and chrysophyte inferred pH is being calculated for the tops (recent; 0-1 cm) and bottoms (pre-1850; >30 cm) of the sediment cores. Numbers of Adirondack lakes that have changed in pH will be estimated using statistical extrapolation procedures developed by the USEPA. Another component of the PIRLA II project is the determination, for a non-random set of lakes, of trends in pH and ANC since 1970, when atmospheric deposition began to decrease in the northeastern USA. This is being accomplished through close-interval (0.25 cm) analysis of surface sediments.

ANTHROPOGENIC DISTURBANCE OF TWO VOLCANIC CRATER LAKES, GUANAJUATO, MEXICO:
A GEOCHEMICAL, ISOTOPIC AND PALAEOECOLOGICAL STUDY

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Since 1981, the Oxford Tropical Palaeoenvironments Research Group has been investigating the palaeolimnological evidence for climatic change in the volcanic highlands of tropical Mexico. These studies revealed several episodes of intense human disturbance during the late Holocene (Metcalf et al 1989). This paper will focus on two small alkaline lakes situated close to the 'arid frontier' of Mesoamerican civilization: Hoya San Nicolas de Parangueo (20° 23'N, 101° 17'W) and La Piscina de Yuriria (20° 13'N, 101° 08'W).

Cores from these lakes have been analysed for loss-on-ignition, carbonate content, magnetic susceptibility, major cations, total P and C: N. The Parangueo core has also been analysed for pollen and the Yuriria core for diatoms and stable isotopes. Their chronologies are based on 15 conventional ¹⁴C dates and 8 accelerator dates, respectively, as well as ¹³⁷Cs measurements on the Parangueo sediments.

Both basins exhibit several phases of enhanced sediment input (weathered soil). The onset of disturbance, dated around 3000 yr BP in Parangueo and 3320 ± 90 yr BP in Yuriria, was associated with the development of maize (*Zea mays*) agriculture during the Preclassic. Geochemical and ¹³C data suggest that lake productivity was suppressed by high turbidity at times of maximum sediment input but reached high levels immediately after disturbance ceased.

Metcalf, S.E., Street-Perrott, F.A., Brown, R.B., Hales, P.E., Perrott, R.A. and Steininger, F.M.

Late Holocene human impact on lake basins in Central Mexico. *Geoarchaeology* (4) 119-141 (1989).

IMPACT OF FOREST DRAINAGE AND PEAT MINING ON LAKES AS REVEALED
FROM SEDIMENT ANALYSES

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Short sediment cores were analyzed from seven Finnish lakes that had received drainage waters from extensive forest ditching and peat mining. Annual laminations were found in the top most sediment of three lakes; other dating methods include ²¹⁰Pb, ¹³⁷Cs and carbonaceous spherules (soot balls).

An abrupt up core decrease in the sedimentary C:N ratio, concurrently with ditching, indicated eutrophication in all the lakes but one, where the unusually high C:N ratio (up to 130) indicated strong inwash of raw peat. Greatly elevated accumulation of Hg was observed in two basins.

The trophic history of the lakes was further examined by means of DCA analyses and CCA analyses of diatom and cladoceran remains together with reference data sets from numerous lakes in Finland. A rise in pH (0.25 to 1.4 pH units, four lakes), considerable pH fluctuations (one lake) and corresponding changes in the inferred alkalinity resulted from the CCA of sedimentary diatoms as a consequence of catchment drainage. This agrees with both the inferred pH-changes seen in diatom index B and in the existing limnological data. The diatom CCA exhibits acidification (0.25 to 0.5 pH units) for two lakes, where the limnological observations reveal eutrophication. *Melosira ambigua* increased in many lakes at the expense of *Cyclotella kuetzingiana*. Other diatoms that benefitted from forest drainage include *Asterionella formosa*, *Melosira perglabra*, *Synedra nana* and *Fragilaria crotonensis*.

The cladoceran CCA displays similar but larger pH changes and the faunal composition also indicates eutrophication in the lakes that acidified. *Bosmina longirostris* increased or appeared up core in all lakes studied together with numerous other taxa of eutrophic waters.

Most of the ²¹⁰Pb datings (CRS model) from sediments of highly erosional origin appeared erroneously old in the light of the dating control by soot spherules.

ANCIENT HUMAN ACTIVITY AND ENVIRONMENTAL CHANGE IN THE HILL-FORT AREA OF
KUHMÖINEN, MIDDLE FINLAND - A PALAEOECOLOGICAL STUDY

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This paper reports biostratigraphical evidence of changing vegetation and effects of disturbances on nature in late Holocene. These are inferred from a comparative analysis of radiocarbon dated soil-pollen, peat-pollen and sediment-pollen records. Emphasis is placed on the value of combining palaeo-evidence derived from a close network of the study sites. The paludified soil site is located in a distinctive hilly habitat of the lake Päijänne region. Prehistoric and historic human disturbance in general is monitored, but special attention is paid on the late Iron-Age - early Medieval times (A.D. 1000 - 1300). Through dendro-ecological investigations on a pine stump for reconstructing a recent local fire chronology it is possible to trace and date several fires in the last past 3 centuries. The combined sedimentary charcoal data helps explaining changes of the fossil pollen assemblages in the diagrams.

The timing and scale of local vegetation changes in the reference area of the church village is clearly shown to deviate from the palaeochronology established for the hill-fort area. Pollen analysis reveals that continuous human activity started in the early Iron Age, and by Medieval times permanent cultivation and pasturage in the former area had created an open landscape with fields concentrated around the church village, while the latter area remained more or less forested wilderness till early 1700's.

The limnological changes in lakes adjoining the hill-fort and in situ burnings of the close peat layers dated to the late Iron-Age - Medieval times and early historic periods (A.D. 1000 - 1800) may be associated with numerous fires occurred in the area. Changes in water-level and increased peat growth, documented by the present data, show significant correspondence with the oldest historical records from the mid-1600's till 1800's revealing the regressive climatic period called as Little Ice Age.

ATMOSPHERIC DEPOSITION AND DIAGENESIS OF TRACE METALS IN PEATLANDS

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Moss and peat from bogs frequently have been used to indicate current and historical rates of atmospheric deposition of trace metals, nitrogen, and sulfur. Implicit behind such use is the assumption that all of these substances behave conservatively in the peat; i.e., that they are deposited on and adhere to surface moss and they do not move subsequently. However, many natural processes facilitate the movement of substances in peatlands, processes including particle wash-down, plant uptake, alternation from oxidizing to reducing conditions, evapotranspirative pumping of water, lateral water flow, partitioning between solid and aqueous phases, and decomposition of organic matter. It is well established that as a result of these processes the historical records of deposition of several elements are not preserved (e.g., Fe, Cs, Ca, Mg), but the extent to which other trace metal profiles are altered remains unknown. To study diagenesis and cycling of trace metals (Al, Fe, Mn, Zn, Pb, Cu, Cd, Ni, Cr), major ions and nutrients (Ca, Mg, Na, K, Cl, NO₃⁻, SO₄²⁻), and radio-nuclides (Pb-210, Cs-137) in peatlands, a large survey of peat bogs in northeastern North America was performed and a small, perched bog in northern Minnesota was studied intensively for 5 years. All inputs and outputs to the Minnesota bog were measured as were accumulation rates in surface and deep peat and above-ground vegetation. Annual cycling through vegetation also was studied. At survey sites, element concentrations were measured in peat and surface waters, and long and short-term accumulation rates were measured in peat. This study has shown that none of the elements studied behave conservatively in peat. Up to 30% of annual Pb inputs to the Minnesota bog are flushed out in the outflow and the historical record of deposition is not preserved quantitatively in the peat. There is a net export of Fe and Al from the Minnesota peatland fed by underlying minerotrophic strata of peat. Mobility of Fe and Al in bogs throughout northeastern North America was governed by the rate of supply (atmospheric deposition) of these elements and partitioning between liquid and solid phases. Large quantities of Zn and Mn are cycled through above-ground vegetation while large quantities of Fe and Al are cycled primarily in the roots. These results have important implications for dating of peat by Pb-210, Cs-137, and magnetic minerals.

HISTORICAL FISH POPULATION STATUS INFERRED FROM CHAOBORUS
STRATIGRAPHY

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The presence or absence of fish has a strong influence on the species of Chaoborus larvae (Diptera: Chaoboridae) present in a lake. In the northeastern United States and Eastern Canada, Chaoborus punctipennis is often dominant. This species exhibits diurnal vertical migration and coexists with fish. Chaoborus americanus, however, is limnetic and does not migrate into the sediments during the day. This species occurs only in lakes without fish, and is usually the dominant Chaoborus species in such lakes.

Paleolimnological analysis of larval Chaoborus remains (primarily mandibles) in lakes of the Adirondack Mountain region (New York, USA) have shown that the stratigraphy of Chaoborus remains reflects the known fish history of the lakes. A shift from a migratory species to Chaoborus americanus indicates the loss of fish from a lake. The presence of Chaoborus americanus throughout a core indicates that fish populations never became established in that lake. Such questions are an important concern in areas which may have been adversely affected by acidic deposition. In terms of assessing the true impact of acidic deposition, it is also important to know if a lake never really had established fish populations.

Further studies are being done of the Chaoborus stratigraphies in some randomly selected low alkalinity lakes from the Adirondacks. This will potentially allow population estimates of the number of low alkalinity lakes in this region which never had established fish populations, and the number which lost fish populations.

Preliminary results from five of the lakes indicated that among three lakes which have apparently acidified in recent years (based on diatom and chrysophyte analyses), two lakes never had established fish populations and one lake lost fish. Among two lakes which have not recently acidified, both historically had and still possess established fish populations.

PIRLA DBMS: THE STRUCTURE AND USE OF A LARGE PALEOLIMNOLOGICAL
DATA BASE

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The PIRLA data base was originally developed for the project, Paleocological Investigation of Recent Lake Acidification. It is continuing to be used and expanded upon during PIRLA II, the set of paleolimnological studies in the Adirondack Mountain region (New York, USA) conducted primarily in the laboratory of John P. Smol at Queen's University.

The main components of the data base are diatom and chrysophyte (both calibration set and stratigraphic) counts from lake cores and associated water chemistry data. Among the other stratigraphic variables entered in the data base are 210-Pb dating, total S, C, N and H data, polycyclic aromatic hydrocarbon data, and total metal data. Lake location and morphometry, diatom and chrysophyte taxa lists, and diatom and chrysophyte ecological preferences are present as well. Investigator names and locations are also included, and the sources and methods for acquiring data are tagged and documented.

Currently, 307 lakes from 5 different geographic regions are in the data base. 216 of the lakes are part of regional calibration sets, while stratigraphic data is entered for 75 lakes. Stratigraphic analyses are in progress for the remaining lakes.

The data base is maintained on a personal computer and uses Scientific Information Retrieval software (SIR/DBMS Version 2.2, revision 18). Currently the data base occupies about 28 megabytes. If auxiliary files are included, the entire data base management system occupies over 40 megabytes of space.

The PIRLA database is primarily hierarchical in structure. Record types (sets of related records, e.g., diatom counts, or chrysophyte counts) are grouped in a hierarchy of levels: region, lake, core, core depth interval, and measurement of sediment characteristic.

The structure of the data base will be described, and examples of data retrievals will be presented. This will serve as an instructive model for others who wish to develop a data base in their own paleolimnological research.

A MULTIPLE CORE STUDY IN THE ACIDIFIED MOORLAND POOL GERRITSFLES, THE NETHERLANDS

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Reconstructions of the acidification history of lakes by paleolimnological methods are affected by the location of the coring sites, because of horizontal heterogeneity of the the sediments, as has been studied by various authors. No such studies are known from shallow pools.

Therefore a multiple core study was undertaken in the moorland pool Gerritsfles (a = 6.8 ha, z_{max} 1.2 m), which developed in an area of aeolian drift sands and heathland in the central part of The Netherlands during the 19th century. Paleolimnological analysis of one core from this pool has demonstrated severe acidification from c. 1900 onwards (Van Dam et al. 1988).

Four cores (length 2-3 dm) were taken for the analysis of diatoms, pollen, seeds, fruits, chironomid head capsules, mineral composition and ²¹⁰Pb. Preliminary results indicate that the two cores from the central, deep part of the pool, which originated in the early 19th century, are very similar. A third core, also from deep water, but close to the margin of the pool, is basically the same as the first two cores, but has been disturbed by trampling of bathers in the early 20th century and probably also sheep washing in the late 19th century. A fourth core, taken in a shallow offshoot, which originated in the late 19th century, is different from the other cores in its basal part, but very similar to the other cores in the topmost decimeter.

Reference: Van Dam, H., Van Geel, B., Van der Wijk, A., Geelen, JFM, Van der Heijden, R. & Dickman, MD (1988). *Rev. Palaeobot. Palynol.* 55: 273-321.

ARCTIC AND ALPINE CHIRONOMID FAUNAS AS ANALOGUES FOR
LATE-GLACIAL COMMUNITIES

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The latitudinal and altitudinal distribution of Canadian Chironomidae is being assessed by means of faunal remains preserved in surficial sediments of lakes. Taxa characteristic of late-glacial deposits in southwestern British Columbia, Canada are presently common in high-elevation lakes of the Canadian Rocky Mountains. Similarly, Heterotrissocladius is common in late-glacial deposits of eastern Canada. Today this genus is widespread at high latitudes.

Many genera common at low elevations throughout temperate North America have not been recorded in arctic or alpine regions. These taxa are probably excluded by low summer temperatures. The presence or absence of thermophilous chironomids in late-glacial deposits should distinguish arctic/alpine habitats from other tree-less palaeoenvironments. The postglacial dynamics of chironomid latitudinal and altitudinal range limits should reflect subsequent climatic events.

SEDIMENTARY DIATOM CONCENTRATIONS AND ACCUMULATION RATES
AS PREDICTORS OF LAKE TROPHIC STATE

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Algal biomass is positively correlated with nutrient concentrations in lakes, though relationships previously have not been established that yield quantitative inferences for nutrient status in historical applications. I developed models that relate the concentrations and accumulation rates of planktonic diatoms in recent sediments to trophic state index (TSI) values for a suite of lakes in Florida, U.S.A.

The best models predict total phosphorus and chlorophyll *a* TSI values from mathematically transformed planktonic diatom concentrations and accumulation rates, and explain approximately half the variance in the dependent variables. In general, annual diatom accumulation rates did not contribute substantially greater predictive capability to models than did sedimentary diatom concentrations. Models that consider the ecological preferences of specific taxa (Whitmore, in press) appear to be better predictors than models based upon diatom concentrations.

Planktonic diatom predictive models may provide a useful secondary line of evidence to assess historical changes in primary productivity, except in lakes where diatom populations have been depressed by silica limitation or by blue-green bacterial inhibition. TSI inferences are presented for sediment cores from two Florida lakes, one of which shows historical limitation of diatom populations, and the other of which does not.

Reference: Whitmore, T (in press) Florida diatom assemblages as indicators of trophic state and pH. *Limnol. Oceanogr.*

THE USE OF CARBONACEOUS SPHERES TO ASSESS RECENT SEDIMENT
ACCUMULATION IN THREE SWEDISH LAKES

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We have tested the hypothesis that carbonaceous spheres, mainly derived from oil combustion and deposited from the atmosphere, can be used to study the spatial distribution of lake sediment. The approach assumes that the number of carbonaceous spheres accumulated at different sites on the lake bottom reflects the recent accumulation rate of sediment. The time perspective is mainly that of the last few decades, since most of the carbonaceous particles are deposited during the post war period.

For three lakes, cores were sampled along profiles from the shore to the deepest part of the lake basin or along transects from shore to shore. Each core, covering at least this century, was homogenized, carbonaceous spheres counted and net accumulation of these particles per unit area of the lake bottom determined.

Results show that in two of the lakes there is a significant correlation between water depth and the number of spheres found. The third lake, however, shows no such correlation. This is an acidified lake in which we believe that normal sediment accumulation processes have been disturbed.

Paleolimnology of Slapton Ley, Devon, U.K.

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Paleolimnological studies of Slapton Ley, a coastal lake in South-West England, reveal the history of its sedimentation, and eutrophication. Chronology was developed by means of ^{210}Pb paleomagnetic and ^{14}C dating (Morey, 1976).

Multiple core studies of magnetic susceptibility demonstrate modern patterns of sedimentation within the Ley, and suggest that the current dry mass accumulation rate is 610t (or 8t ha^{-1}) a^{-1} , equivalent to an erosion rate from its catchment of ca. $47\text{t km}^{-2} \text{a}^{-1}$. The main source of sediment for the Ley is at present agricultural land in its watershed.

Diatom studies of the uppermost 40cm of the sediments indicate that since the 1960s, the flora has become dominated by centric species, indicating further eutrophication since ca. 1976.

Reference: Morey, C. (1976). The Natural History of Slapton Ley Nature Reserve IX The morphology and history of the lake basins. Field Studies 4, 353-368.

PALEOLIMNOLOGICAL STUDIES OF SEDIMENTS OF LAKE TEGELER SEE (WEST GERMANY)

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Lake Tegeler See is situated in the North German low lands (13°15' West, 52°34' North) once covered by the Weichselian glaciation. The catchment area consists of fluvioglacial sand, ice marginal sand, gravel and marl. The lake drains into the slow flowing river Havel, which has a lake like appearance in the Berlin region. The lake's average depth is 8 m, reaching a maximum of 16 m, it covers about 4 km².

Sediments were investigated to elucidate the lake's paleolimnology. Cores were taken in the main basin of the lake (water depth 8 m) and in the transition zone to Havel (water depth 5 m). The cores reach sediments of the Sub-Boreal and the Early Atlantic period respectively. Subfossils of pollen, diatoms and microfauna were differentiated and chemical analyses were performed.

Results were related to water level changes, hydrology, water stratification, allochthonous inputs, anthropogenic impact and metabolic processes in the water and at the sediment. They suggest an inflow of water from the Havel river and an increase of primary production since the Late Atlantic period. The diatoms were decomposed in the studied sediments in the Sub-Boreal period possibly due to bioturbation. In the Early Sub-Atlantic period productivity decreased again. Sapropelic sediments and increased concentration of trace metals in the upper sediment indicate heavy pollution in the industrial period.

OSTRACODA OF THE ENGLISH LAKE DISTRICT.

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Fossil ostracods may record historical changes in the water chemistry of lakes and other water bodies, both in the species composition of assemblages and in their shell chemistry. Fossils in lake sediments can be used to assess the effects of acid deposition on aquatic systems; to date, the majority of such studies have been on diatoms. Ostracods offer the possibility of augmenting the diatom data and providing additional information on both short- (months or weeks) and long-term (years) changes in water chemistry, firstly because they incorporate into their valves Ca and other minerals taken directly from the water at the time of moulting, and secondly because it is known that species differ in their environmental requirements, particularly with regard to pH and Ca concentrations. The chemical conditions tolerated by individual species and the influence of water chemistry on valve composition and preservation are inadequately understood, especially with regard to British species. If our knowledge on these topics can be improved then the potential of ostracods as environmental indicators can be more fully exploited.

Ostracods are being collected from lakes and tarns in the Lake District, where water chemistry data are already available. Selected species will be cultured in waters of different chemical composition; analyses will be carried out to determine the degree to which shell composition reflects water chemistry and whether post-mortem changes in shell chemistry occur. Comparisons between the results of the field survey and those of laboratory experiments should provide an insight into the relationship between ostracods and water chemistry and ultimately provide a yardstick for the detailed interpretation of past environments on the basis of fossil ostracods.

Here we present preliminary data on the distribution and ecology of Lake District ostracods, about which little was known until quite recently; a list of 27 species published by Horne (1988) more than doubled the number previously recorded in the area.

Reference: Horne, D.J. 1988 Freshwater Ostracoda of the Lake District.
British Micropalaeontological Society Field Guide No. 7, 28 pp.
University College of Wales, Aberystwyth.

HIGH PRECISION ABSOLUTE DATING OF LATE QUATERNARY LACUSTRINE SEDIMENTS
BY MEANS OF ANNUAL LAMINATIONS

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Annually laminated lake sediments (=organic varves) provide a lot of paleolimnological informations. The most important demand for all investigations is absolute dating of these sediments. Using a varve chronology an absolute age determination has been worked out from sediments of Lake Holzmaar and Lake Meerfelder Maar (Eifel Mountains, West-Germany). Basic requirement is a continuous and undisturbed sediment profile, cored in the profundal, consisting at least of two overlapping core series. Coring and preparation should be carried out without any significant alteration of sediment structure.

The most precise counting of varves is obtainable only by light microscopic analysis of thin sections from the annually laminated sediments. Thus the annual character might be proved by palynological and diatomological methods. Reduction of interpreting and counting errors is another advantage of thin section examination.

The investigated late- and post-Glacial sediments lead to a dating accuracy of $\pm 1.1\%$. This error results mainly of indistinct and ambiguous annual laminae. Subdivision in three periods of different accuracy is possible:

1. late-Glacial (12,800 - 10,000 BP) with a high error of $\pm 5.5\%$;
2. early- and mid-Holocene (10,000 - 3,600 BP) with errors below $\pm 1\%$;
3. the last 3,600 years with intermediate error of ± 3 to 4% .

The varve dating of the isochrone of Lake Laach Pumice Tuff results in 9,200 years BC, confirming the accuracy of the method. Time calibration of paleomagnetic measurements leads to inclination and declination curves, similar to the radiocarbon dated United Kingdom type curves of TURNER & THOMPSON. Times of intensified anthropogenic activity in the lake's drainage basin, preserved in the sediments, agree with prehistorically and historically documented periods of colonization in that area since Neolithic times. Just the varve chronological dating of the palynologic chronozones differs from the known classification. This might be due to local effects or to systematic errors in radiocarbon dating.

Varve chronology is a valuable tool for sediment dating, providing a precise absolute and continuous dating in sidereal years.

**ANTHROPOGENIC INFLUENCES AND CLIMATIC FLUCTUATIONS
RECORDED BY MINEROGENIC SEDIMENT INPUT**

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Annually laminated sediments of Lake Holzmaar and Lake Meerfelder Maar provide a good tool for examination of environmental processes in the drainage basins. Variations of the clastic components sand, silt and clay in prevailing organic varved deposits are believed to be an indicator of soil erosion in the catchment area. Stable soils develop under a dense vegetation. In cases of very cold climatic conditions the plant cover is sparse and soils are exposed to rain and storm. In consequence erosion is high. Periods of high precipitation also may cause intensified erosion. Finally human clearing and colonization activities lead to a less stable ecosystem with enforced erodibility. Thus the uppermost soil horizon is exported from the drainage basin into the lake, where it is trapped forming a part of the sediment.

Absolutely dated sediment increase diagrams enable to read these events of sedimentation in detail.

With exception of Subboreal times, when strong diatom blooms increase sedimentation, the peaks are produced only by enlarged input of clastic components. The distinction in natural and anthropogenic causes results from microscopic proof of wood and/or charcoal remnants due to woodland clearing and from temporal position of the peaks.

Determination of organic carbon, water contents and magnetic susceptibility support these results.

With the onset of the late-Glacial clastic input decreases drastically, due to a closing vegetational cover caused by warmer temperatures. Lake Laach Pumice Tuff appears as a distinct marker. Climatic fluctuations lead to peaks in sediment increase rate during Younger Dryas and Preboreal. Very low amounts of sediment are deposited during the Boreal and Atlantic climatic optimum as a consequence of high soil stability. The following Subboreal shows three peaks correlated with diatom blooms which are probably caused by human eutrophication according to Neolithic and Bronze Age settlements. In Subatlantic times the beginning Iron Age leads to extensive losses of woodland. Agriculture is accompanied by erosion resulting in very high sediment increase rates. Two other peaks result from Roman colonization and the onset of the Middle Ages.